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ELECTRICAL SECTION.

Stated Meeting held Tuesday, November 28, 1899.

CAST WELD AND SURFACE CONTACT BONDS.

BY W. E. HARRINGTON,
Electrical Engineer, Member of the Section.

To determine definitely the electrical resistance of cast weld joints under various conditions with and without bonds, Wm. Wharton, Jr., & Co. kindly poured two joints around two pieces of 9-inch girder rail each 3 feet long. One joint was provided with flat copper bond made up of two pieces of copper, 4 x 5½ x ⅛ inches, securely contacted with the rail web upon each side of web, with iron plates 6 x 6½ x ¼ held by four ⅞ x 2½ bolts, as shown in following sketches, *Figs. 1, 2* and *3.*

The cast weld joints were poured, having the general dimensions as shown in sketch, *Fig. 4,* two of the fish plate holes showing. The Weston milli-voltmeter was connected 24-inch centers upon head of rail, or 12 inches each side of joint.

The method of testing adopted was to obtain the drop in voltage or difference in potential around the various joints, the milli-voltmeter connections made upon 24-inch centers. The resistance in ohms of 24 inches of solid rail section was first obtained by measuring the drop in volts in 18 inches and reducing it to 24 inches. Weston instruments were used.

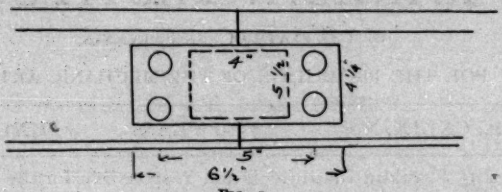

FIG. 1.

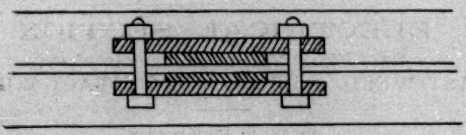

FIG. 2.

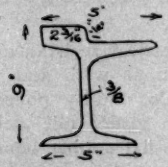

FIG. 3*a*.

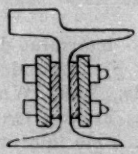

FIG. 3*b*.

The contacts of the milli-voltmeter were made through contacts made with Edison-Brown alloys. The resistance of the solid rail was used as a basis of comparison.

The tests were made by placing the rail with its joint in series with an ammeter, circuit breaker, switch and water rheostat and taking readings of the drop in milli-volts at each reading of current in ampères as shown upon ammeter.

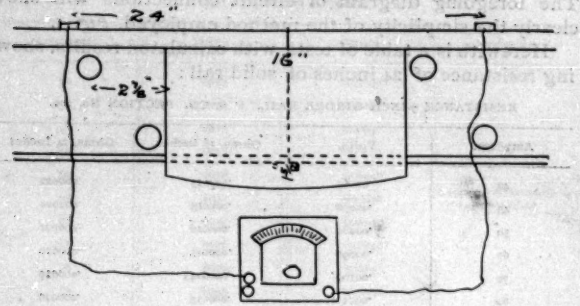

FIG. 4.

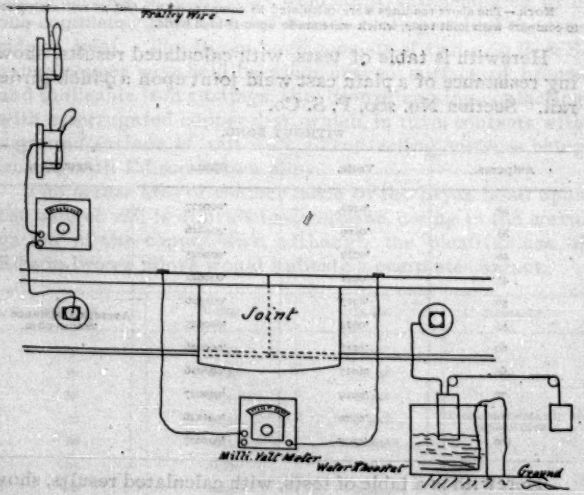

FIG. 5.

The foregoing diagram of circuit connections will show clearly the simplicity of the method employed, *Fig. 5*.

Herewith is a table of tests, with calculated results, showing resistance of 24 inches of solid rail:

RESISTANCE 9-INCH GIRDER RAIL. P. S. CO. SECTION No. 200.

Ampères.	Volts.	Ohms, 18 Inches.	Ohms, 24 Inches.
40	·00060	·000015	·000020
45	·00070	·000015	·000020
50	·00080	·000016	·000021
60	·00090	·000015	·000020
70	·00100	·0000143	·000019
80	·0012	·000015	·000020
90	·0014	·000015	·000020
100	·0016	·000016	·000021

Average resistance 24 inches = ·00002 ohm.

NOTE.—The above readings were calculated to compare with 2 feet of rail resistance, to compare with joint tests, which were made upon 18-inch basis.

Herewith is table of tests, with calculated results, showing resistance of a plain cast weld joint upon a 9-inch girder rail. Section No. 200, P. S. Co.

WITHOUT BOND.

Ampères.	Volts.	Ohms.	Remarks.
30	·0008	·000027	
35	·0009	·000026	
40	·0010	·000025	
45	·0011	·000024	
50	·0013	·000026	
55	·0014	·000025	Average resistance = ·000026 ohm.
60	·0016	·000026	
65	·0017	·000026	
70	·0019	·000027	
75	·0020	·000026	
100	·0027	·000027	

Herewith is a table of tests, with calculated results, showing resistance of cast weld joint with plates contacting with each side of rail, as shown above, as per sketch No. 1:

JOINTS WITH BONDS.

Ampères.	Volts.	Ohms.	Remarks.
30	·0012	·000040	
35	·0014	·000040	
40	·0016	·000040	
45	·0018	·000040	
50	·0020	·000040	
55	·0022	·000040	Average resistance = ·00004 ohm.
60	·0024	·000040	
65	·0026	·000040	
70	·0028	·000040	
75	·0030	·000040	
100	·0040	·000040	

Herewith is a table of tests, with calculated results, showing resistance of plain cast weld joint, supplemented with one complete "Bryan" bond 24-inch centers around the outside of joint. The Bryan bond consists of two 4/0 B. & S. gauge copper wire held between curved surface of bronze and malleable iron castings, the bronze casting contacting with a corrugated copper disk, which, in turn, contacts with a ground surface of rail web, all contacting surfaces being treated with Edison-Brown alloy.

The actual area of contact made by the Bryan bond upon the web of rail is difficult to determine, owing to the corrugation of the copper disk, although the plentiful use of Edison-Brown alloys would indicate a complete contact.

Ampères.	Volts.	Ohms.	Remarks.
40	·00070	·000017	
50	·00090	·000018	
60	·0011	·000018	
70	·0013	·000018	Average resistance = ·000018 ohm.
80	·0015	·000018	
90	·0017	·000018	
100	·0019	·000019	

A plain cast weld joint was taken and a hole ¼ inch in diameter by ⅛ inch deep was drilled between the bottom rail ends down to the cast weld, as shown in following sketches, *Figs. 6* and *6b*.

The metal was so hard the drill would hardly cut it; the drill was run, using soda water as a lubricant. The hole was cleaned out and thoroughly amalgamated with Edison-Brown alloys, and finally filled up to the surface with Edison-Brown flexible solder. The result of the test, showing

FIG. 6.

FIG. 6b.

the drop in voltage and ohmic resistance, is shown in the following table:

Ampères.	Volts.	Ohms.	Remarks.
30	·0006	·000020	
40	·0009	·000022	
50	·0011	·000022	
60	·0013	·000022	Average resistance — ·000021 ohm.
70	·0016	·000021	
80	·0018	·000022	
90	·0020	·000022	
100	·0022	·000022	

The plain cast weld joint was again taken, the amalgam removed from hole and a piece of sheet copper 30 inches long by 4 inches wide by $\frac{1}{8}$ inch thick with two $1\frac{1}{16}$-inch holes punched therein was placed to go around the cast weld joint and contact with the rail web in the same holes that the test had been made previously, with the Bryan bond upon 24-inch centers, the contacts were thoroughly amalgamated with the Edison-Brown alloys.

Washer plate 4 inches square was used with 1-inch bolt and lock washer to hold each of the two ends in form and positive contact with the rail web.

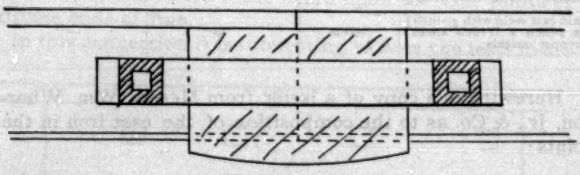

FIG. 7.

Herewith is a sketch of the connections and form of bond, *Fig.* 7.

The area of contact upon each of this bond is 15 square inches.

Herewith is table showing the results of the ohmic resistance and voltage.

Ampères.	Volts.	Ohms.	Remarks.
30	·0004	·000013	
40	·0006	·000015	
50	·0008	·000016	
60	·0010	·000016	Average resistance — ·000016 ohm.
70	·00128	·000017	
80	·00130	·000016	
90	·00150	·000016	
100	·00160	·000016	

CAST WELD JOINT ELECTRICAL TESTS. SUMMARY OR COMPARISONS OF TESTS.

Test.	Ohms.	Percentage Comparisons of Resistance of each Test with the Resistance of Solid Rail Resistance.	
		Per Cent. Less	Per Cent. Greater.
Solid rail	·000030	—	—
Plain cast weld	·000026	—	30
Cast weld with copper contacts, *Fig. 1*	·000040	—	100
Plain cast weld with 2—4/0 Bryan bond	·000018	10	—
Plain cast weld with ½ x ½ Edison-Brown alloy plug	·000031	—	5
Plain cast weld with 30-inch x 4-inch x ⅛-inch sheet copper outside	·000016	20	—

Herewith is a copy of a letter from Messrs. Wm. Wharton, Jr., & Co. as to the composition of the cast iron in the joints:

PHILADELPHIA, June 3, 1898.

Subject—Recomposition of iron in test joints.

MR. W. E. HARRINGTON,
General Manager Camden and Suburban Railway Company.

DEAR SIR:—Referring to the matter of the composition of the cast weld joints made for your experiments day before yesterday, we beg to say that the joints were run in with other work, and no record was kept of what heat they were taken from, but to the best of our judgment the following would be the result of an analysis of this metal:

Iron	92·66
Combined carbon	·30
Graphite	3·45
Silicon	2·25
Sulphur	·04
Phosphorus	·70
Manganese	·60
Total	100·00

Trusting this will answer your purpose, we remain,

Very respectfully,
WM. WHARTON, JR., & CO., INCORPORATED,
(Signed) A. B. KIBBE,
Engineer of Construction.

TRACK TESTS OF JOINTS.

Various attempts were made to test joints in street by using a water rheostat and making connection to overhead trolley, assuming that current would flow through joint either from or to the power station according to the manner the power station is connected.

The results obtained from this method were of such a variable character as not to be depended upon, owing to the uncertainty of the amount of current flowing through the joint.

The only tests which gave correct results, under the above conditions, were those made upon the last joints at extreme ends of line.

In this connection it is interesting to note the tests made

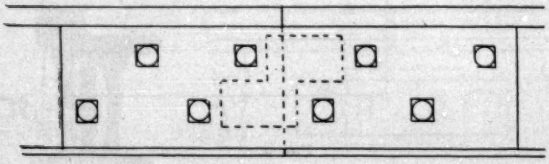

FIG. 8.

under the latter condition upon 7-inch girder rail, Pennsylvania Steel Company's Section No. 238, with an eight-bolt, 26-inch fish plate, using Ajax bond, as per sketch, *Fig. 8.*

Herewith is schedule of tests:

Ampères.	Volts.	Ohms.
20	·0004	·00002
30	·0006	·00002
40	·0008	·00002
50	·0010	·00002
60	·0012	·00002
70	·0014	·00002
80	·0016	·00002
90	·0018	·00002

The above tests were made with the Weston milli-voltmeter connected upon 24-inch centers.

The remarkably good results obtainable from the use of the large, broad area of contacts in the sheet copper bond employed around the cast weld joint emphasized the correctness of the use of the sheet copper contacts for bonding purposes under fish plates, when such construction was used.

Various bonds were made up to suit the requirements

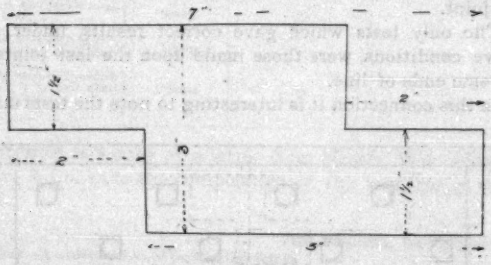

FIG. 9.

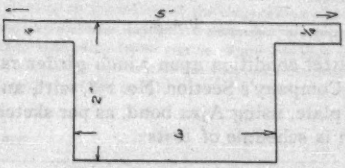

FIG. 10.

of different rail sections, fish plates and drillings. Herewith are dimensional sketches of several sizes:

Ajax bond for 7-inch girder rail, Cambria Iron Company's section No. 824, under 26-inch-long fish plates, staggered bolts, *Fig. 9.*

Ajax bond for 7-inch girder rail, Pennsylvania Steel Company's section No. 238, under 26-inch fish plate, six bolts, *Fig. 10.*

Ajax bond for 9-inch girder rail, Pennsylvania Steel Company's section No. 200, under 32-inch fish plates, twelve bolts, *Fig. 11*; also *Figs. 11b, 11c, 11d.*

The Ajax bonds, as illustrated above, consist of a piece of copper pressed against the abutting rail ends through the medium of cupped ½-inch set screws bearing against a

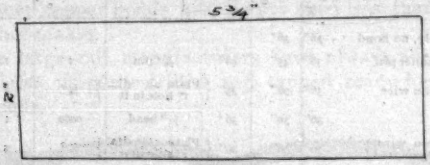

FIG. 11.

FIG. 11*b*.

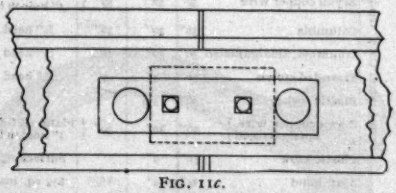

FIG. 11*c*.

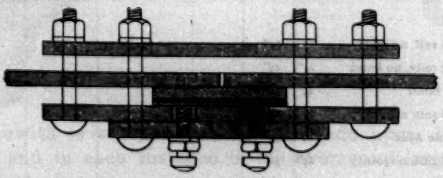

FIG. 11*d*—Special form illustrating Ajax Bond.

thick superimposed piece of steel to divide and distribute the pressure.

The rail is ground off, exposing a clean metallic surface, and then treated with any practicable mercuric compound to amalgamate the rail to prevent oxidation.

Repeated tests were made upon the above sizes, and the average of the results is shown in the large schedule of tests.

The conclusion to be drawn therefrom is quite interesting. It shows that the ohmic resistance is quite comparable with the resistance of the rail section itself, and, if

	Kind of Bond.	C. to C. of M. V. Contacts.	Center to Center of Contact.	Length of Bond.	Size of Contact.	B. & S. Gauge.	Number of Wires in Bond.	Ohms.
Penna. Steel Co. 7" Girder Rail No. 238	Joint only, no bond	36"	36"					·00071
	Iron channel pin	36"	43"	48"	⅞" pin	0	1	·00049
	Bryan iron wire	36"	36"	35"	Plate 2¾" dia. 1" hole in it	¼"	2	·000286
	Crown	36"	30"	35'	⅜" head	0000	1	·000247
	Bryan iron wire, amalgamated	36"	36"	39"	Plate 2¾" dia 1" hole in it	¼"	2	·000224
	Crown, amalgamated	36"	30"	36"	⅜" head	0000	1	·000185
	Bryan copper wire	36"	36"	39"	Plate 2¾" dia. 1" hole in it	0000	2	·000175
	Columbia	36"	30"	36"	⅜" head	0000	1	·000131
	Columbia, amalgamated	36"	30"	36"	⅜" head	0000	1	·000126
	Stranded crown	36"	5"	7"	⅜" head	0000	1	·0001
	Plastic socket	36"	3¼"					·000093
	Bryan copper wire, amalgamated	36"	36"	39"	Plate 2¾" dia. 1" hole in it	0000		·000071
	Plastic cork	36"	9"		Surface 1¼"			·00006
	Ajax bond	24"	24"	8½"	8½ sq. ins.	¼ sq. in. section		·000041
Wharton No. 58 60 lb. T.	Solid rail, no joint	24"	24"					·000024
	Joint only, no bond	24"	24"					·0015
	Ajax bond	24"	24"					·000048
	Solid rail, no joint	24"	24"					·000035
	Double Ajax	24"	30"					·00004
	Solid rail, no joint	24"	30"					·000035
6" P.S.Co. 35 lb. Sec. 200 T.	Ajax bond	24"	24"					·000051
	Solid rail, no joint	24"	24"					·000044
	Ajax bond	24"	24"	5¾"	5¾ sq. ins.	⅛ sq. in. section		·000031
	Solid rail	24"	24"					·00002

double bonding be employed, the resistance can be made less than rail resistance with far more certainty of result than that obtainable from any of the types of bonds expanded in the holes in foot or web of rail.

The features in the bond are such that they commend themselves at once, owing to ample and liberal contacts, adjustable means for renewing contact, the knife blade switch type construction and the absolute freedom from the inevitable loss or breakage, with consequent "scraping" of bonds, so frequent in all the other types employed.

The writer has found that the total cost from placing the sheet copper bonds has always been less than placing the other makes.

The large rail manufacturers have always finished the fish plates properly drilled and tapped ready for placing the bonds.

FIG. 12.

FIG. 13.

Herewith is a schedule of tests made upon different bonds, and in each instance is the average of large numbers of tests:

Figs. 18, 18b, 18c, 18d, 18e illustrate the most recent form of Edison-Brown bond located under fish plate, but depending upon the Edison-Brown alloys for contact.

CONCLUSIONS.

(*a*) The cast weld joint alone has a resistance 30 per cent. greater than the solid rail section.

(*b*) The use of sheet copper, as furnished by the Ajax Company, makes the combined resistance 20 per cent. less than the solid rail section.

(*c*) Where the cast weld joint is not employed and the usual fish-plate form of construction adopted, the flat sheet surface contact form of bond, known as the "Ajax," makes

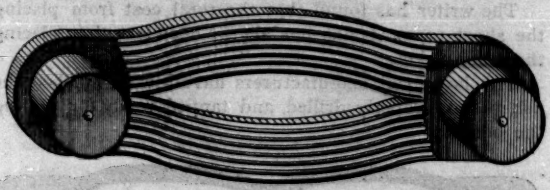

FIG. 14.

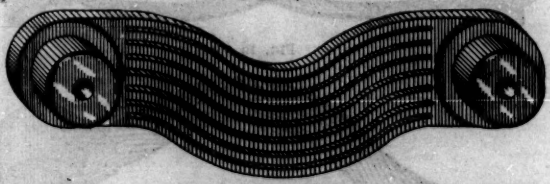

FIG. 15.

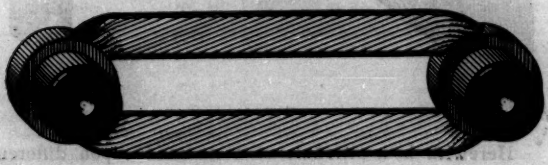

FIG. 16.

the most efficient type of bond, both electrically and mechanically, making resistance only slightly more than the rail section against the other types of bonds, as shown on table of tests, whose resistance runs from three to four times more.

General.—The trend of practice has been during the last year or two to use a form of bond to be placed under the fish plate, instead of around the outside of the fish plate.

In the types which have heads *riveted* or *expanded* into the rail the leads are made flexible to provide for rail movement, caused by expansion and contraction and vertical movement of rail following the passage of cars over joints.

Herewith are shown cuts illustrating some of the types most frequently used, *Figs. 13, 14, 15* and *16*.

As mentioned above, tests have demonstrated that the bonds making *superficial contact* with the web of the rail instead of contacting with the side of a hole through the web are the most efficient and economical design.

FIG. 17—The Conant rail-joint testing instrument.

There is a battle royal raging between the exponents of the hole type as to what constitutes the best method of preparing the hole and placing the bond.

One concern punches out the hole with a hydraulic press and places the bond head in the rough irregular hole and expands the bond head by similar means in the hole, whilst an engineer in New York goes so far as to drill the hole, then ream, followed by pressing hardened steel balls, through a hole in bond in order to provide an accurate fit.

FIG. 18.

FIG. 18*b*.

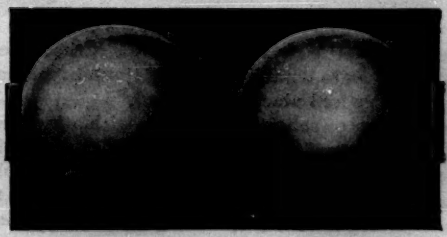

FIG. 18*c*.

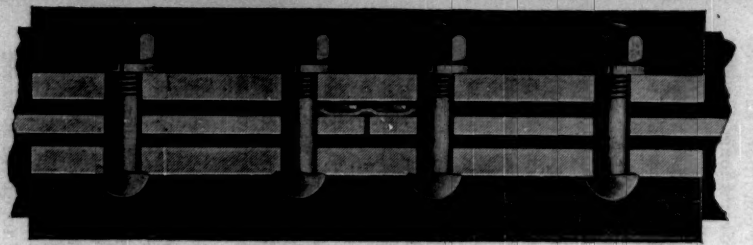

FIG. 18*d*—Illustrations of the most recent forms of the Edison-Brown mercury type of bond.

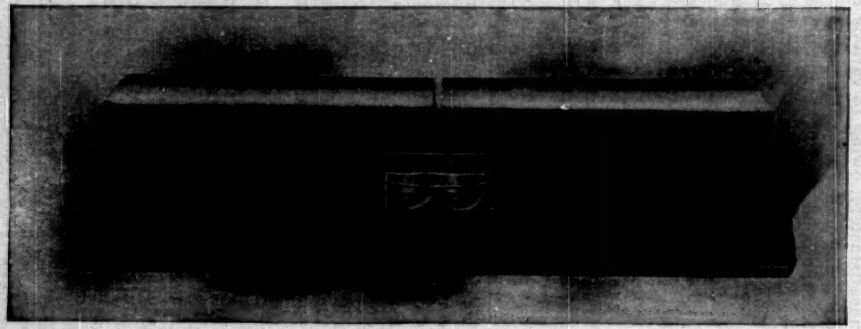

FIG. 18*e*—Illustrating Edison-Brown mercury bond.

Testing.—As to testing rail bonds, practical tests after rails and bonds are placed are exceedingly difficult and unsatisfactory, owing to various factors which interfere in obtaining uniform readings. Our experience has been to test the bond carefully under laboratory conditions and then watch the bond while in practical use over a long period of time as to mechanical or physical changes.

Herewith is shown a cut of a device, *Fig. 17*, advertised as being a practicable, testing device, probably within ordinary requirements will give a means of roughly determining the relative relation of resistance of bond to that of rail in terms of length of rail. The principle is that of comparing by the "null" method of measurement, using a telephone to determine the resistance of the joint to such a length of rail that the rail resistance will balance the bond resistance.

NUMBER OF BONDS TO BE PLACED.

The question has often been discussed as to what extent bonds should be placed. Some contend to place bonds so the conductivity of the joint will be equal to the rail section. Others contend that the conductivity be made equal to the feeder system. Others again contend that the bonding be done to provide for the flow of current through joint, the joint is calculated to carry under normal conditions, basing the carrying capacity of copper as 1,000 ampères per square inch of cross-section, and 100 ampères per square inch of contact.

The writer believes the latter method the best under ordinary conditions, as the first method, while theoretically the best, still is almost impossible to pursue in all cases for various reasons, such as the cost, mechanical difficulties, etc. Where cast weld joints were employed the writer, however, was successful in making the resistance of the joint actually 20 per cent. less than the resistance of a corresponding rail length.

CARRYING CAPACITY OF RAILS.

The cross-section of standard girder rails is closely approximate, the same number of square inches as the rail

is high; for instance, a 7-inch girder has a cross-section of 7 square inches, a 9-inch girder, 9 square inches.

As the conductivity of copper is to iron in the ratio of approximate 7 to 1, it follows that a 7-inch girder rail has the conductivity of 1 square inch of copper, while a 9-inch girder has the conductivity of $1\frac{1}{4}$ square inches of copper, and the two rails of such a track would have a conductivity of $2\frac{1}{2}$ square inches of copper. One can readily see to attempt to bond to the carrying capacity of the rail would be an exceedingly expensive undertaking. Of course it may be necessary upon the trackage approaching the power station.

Read at the stated meeting held November 28, 1899, and discussed at the stated meeting held February 27, 1900.

INCANDESCENT LAMPS.

By Francis W. Willcox.

(*Concluded from page 369.*)

CANDLE-POWER PERFORMANCE.

Tests of this character have frequently been made, but not always with a regard to the necessities of the case. Curves of candle-power have often been published without any statement of the efficiency at which the lamps were started.

This is of the first importance—to have the efficiency definitely known and accurately determined to within $\frac{1}{10}$ of a watt. It is not generally appreciated how important this is. A difference of $\frac{1}{10}$ of a watt per candle is sufficient to make a difference of 100 hours of life performance. Therefore in testing it is a prime requisite to have lamps under test start at an exact equality in average efficiency. If the lamps pass the initial test as to close rating, then the number to be set up for life test can be selected so as to average the desired efficiency. For example, in the case of lamps on diagram, *Fig. 2*, we would select for test those along the 3·1-watt line. The economy chosen as a basis for

test is generally the highest possible, as this shortens the period of test. For this reason 3·1 watts per candle is preferable, as test need not be continued longer than 400 hours, while with 3·5-watt lamps the period would be over 600 hours, and with 4-watt over 1,200 hours.

Not only must economy be exact, but the candle-power and voltage must be similar. It will not do to compare 50-

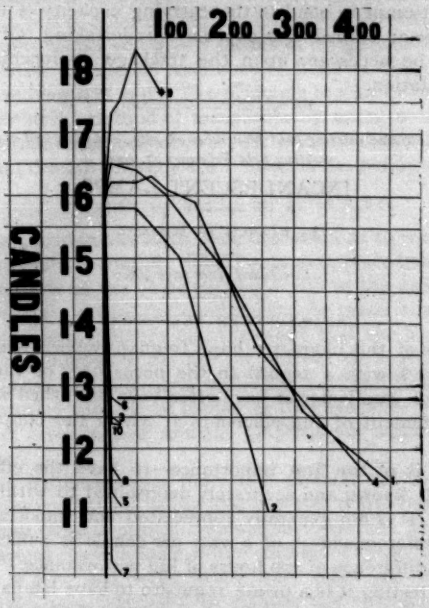

FIG. 6.—Candle-power performance diagram, showing poor results given by ten 16-candle-power 100-volt lamps—3½-watt lamps.

volt lamps of one make with 100-volt of another, or 10 candle-power with 16 candle-power.

The number of lamps to be tested should preferably be twenty-five or more of each make, and never less than ten. Any less number is not sufficient to give a safe average.

The voltage during test should always be kept normal and constant. An average increase of but 1 volt in pressure during test will decrease the result 10 per cent., and a volt decrease in pressure will increase results in same ratio.

The candle-power readings may be continued indefinitely, but the practical method is to continue results to some

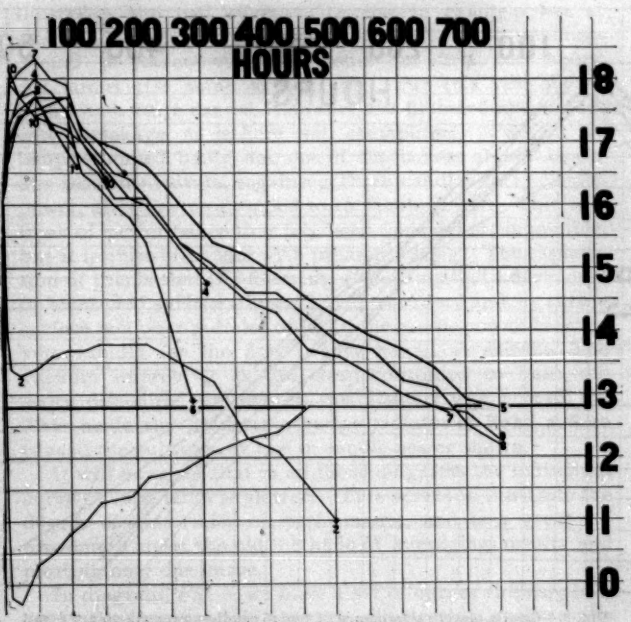

FIG. 7.—Candle-power performance of ten lamps, 16 candle-power 112-volt 3½-watt lamps, showing lack of uniformity in performance.

agreed limit of comparison. The limit most generally taken is 80 per cent. of the initial candle-power, which would be, for the 16 candle-power lamp, the 12·8 candle-power line.

Here are several sets of candle-power tests* plotted on diagrams in the usual manner, with the ordinates representing candle-power and the abscissæ hours of burning. An examination of these will show us some features of interest.

Diagram, *Fig. 6*, shows the miserable results some makes

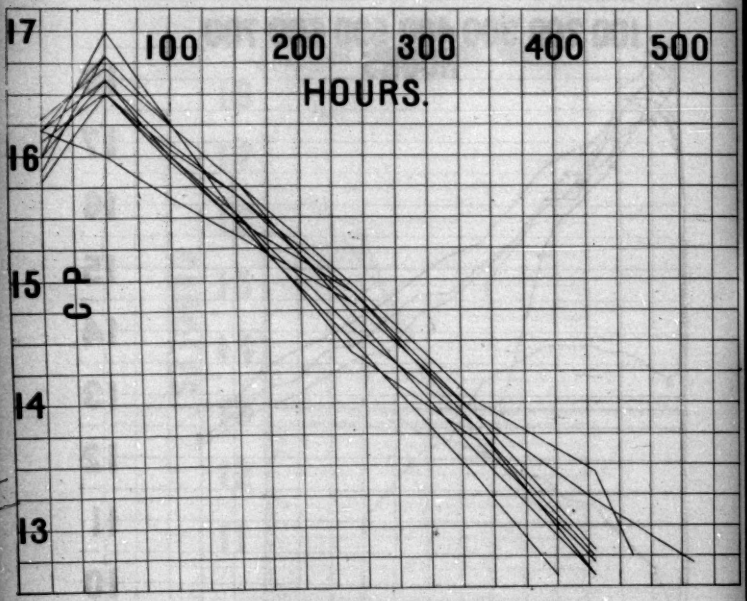

FIG. 8.—Candle-power performance of ten 16 candle-power 112-volt 3·1-watt lamps, showing uniform and good results of well-made lamps.

of lamps will give. Here are ten lamps set up at an average economy of 3·5 watts per candle, and six of them lost over 20 per cent. in candle-power inside of ten hours, only three lamps giving any life at all. Such a lamp no station could

* The writer wishes to acknowledge indebtedness to the Association of Edison Illuminating Companies for many of the diagrams used herein.

afford to use even if a bonus were paid on each lamp. Yet the manufacturer of this lamp glibly made a contract with the United States Government to furnish lamps under specifications that not more than three manufacturers in the world could regularly fulfil.

Diagram, *Fig.* 7, exhibits an interesting set of curves of ten lamps started off at 3·12 watts per candle. This illustrates the bad effects of a rise in candle-power at starting. Owing to this rise in candle-power, readings should be taken every 25 hours for first 100 hours. All lamps rise some at the start, but this rise should be limited, as, in excess, it strains the filament and causes early breakage, as is here well exemplified. Two of the lamps slumped badly, and one of the curves shows a curious recovery feature, regaining three candles to 13 candle-power, after having dropped to 10 candle-power. This is a freak of performance that has been considered impossible, but it is quite often met with in lamp testing. The explanation of this is that the filament of the lamp had a discolored or blackened surface (through bad vacuum), and, as such a surface is a poor radiator of light, the candle-power declined very rapidly for the first twenty hours, as shown. The vacuum improving as the lamp continued to burn, the sooty, discolored coating on the filament was burned off. This made the filament a better radiator of light, and so caused the subsequent rise in candle-power shown.

It will be noted that in all these diagrams the individual curve of each lamp is plotted. This serves to illustrate the degree of uniformity of performance, and is a great improvement upon the old methods of averaging results and plotting only one curve.

In diagram, *Fig.* 8, we have a set of curves showing how well-made lamps should perform—illustrating good results and great uniformity.

Compare this with *Fig.* 9, showing results on ten lamps taken at random from a barrel sold for 16 candle-power 3·1 watts per candle, an excellent example of poor results.

A proper measure for lamp value should include both

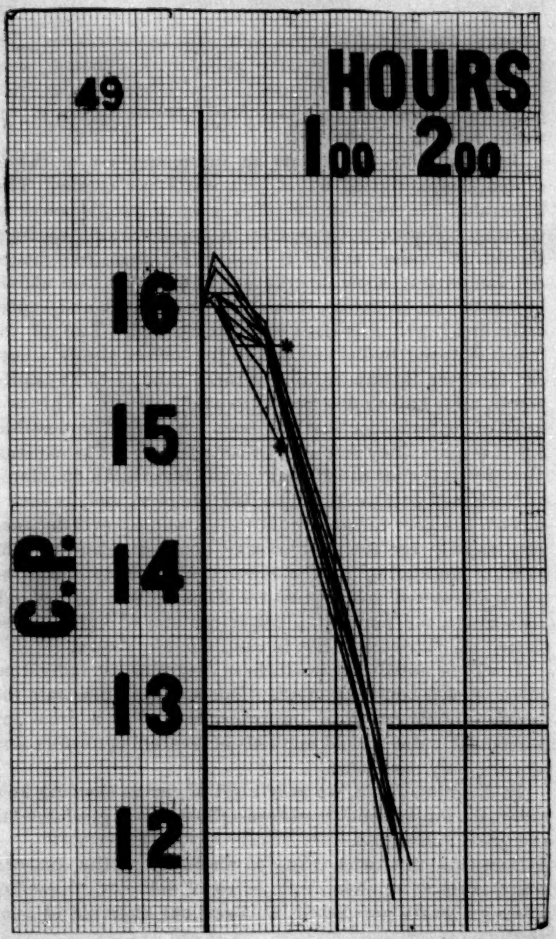

FIG. 9.—Candle-power performance of ten 16 candle-power 115-volt 3·1-watt lamps, showing rapid decline of candle-power.

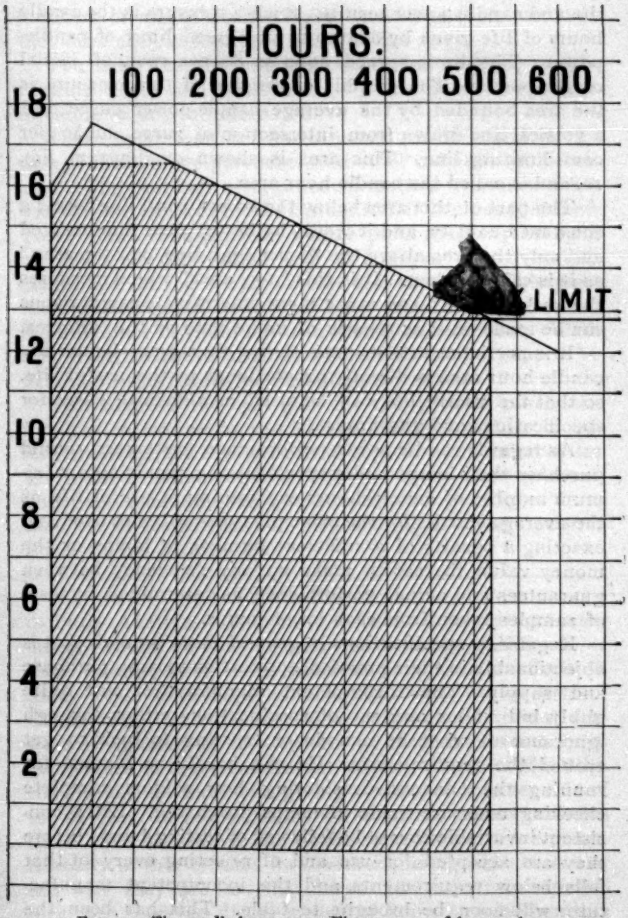

FIG. 10.—The candle hour area. The measure of lamp value.

life and candle-power results. Such a measure is the candle hours of life given by a lamp to an agreed limit of candle-power. The limit agreed upon is 80 per cent. of initial candle-power. The graphic expression of this measure is the area bounded by the average candle-power curve and a vertical line drawn from intersection of curve and 80 per cent. limiting line. This area is shown on diagram, *Fig. 10*, and is called the candle hour area.

The part of this area below the 80 per cent. line forms a constant quantity, and it would be better were this omitted and only the area above the 80 per cent. line, or "top area" as it is called, taken. It is this "top area" which measures the useful results, and much more determinate comparisons can be made on it as a basis of value than on the full area.

It is pertinent to also note that with normal lamps the candle hour area is directly proportional to the useful life, so that the useful life can be used as a definite basis for specifications and guarantees.

As regards candle-power performance, customers should purchase their lamps under specifications requiring a minimum number of candle hours or a minimum useful life as the average results for the principal types of lamps used and exacting a penalty of a sufficient number of lamps or the money value thereof to make up any deficiency between guarantees and actual performance, as determined by tests of samples taken from each lot of lamps.

Regarding specifications in general there is much that is objectionable in their practical application to lamp purchase and supply. The incompetent manufacturer will quite glibly bid under any set of specifications either through ignorance of what he can do or trusting to luck to get around the requirements. He can hardly be blamed for running the chances, considering how seldom complete checking tests are made of lamps purchased. Let a consistent invariable course be followed of testing lamps before they are accepted for use and of rejecting every lot that falls below requirements, and the incompetent manufacturer will soon be brought to table. This has been the policy of the U. S. Navy, and it is a well-known fact that

numbers of manufacturers have learned to their cost that they dare not bid to supply lamps to the navy.

The navy keeps a sufficient stock on hand to supply running needs and tide them over the delay due to the rejection of any lot purchased.

These conditions are, however, not to be found in the case of the average purchaser, and other methods are necessary. The best and most practical method, it seems to me, was the one adopted by the Standard Oil Company, of New York. This company last winter purchased in the open market some fifty lamps each of a dozen of the leading makes and carried out a complete test thereon. This gave them positive data as to what lamp gave best results, and the difference in value between it and the next best. With this information in hand the selection of the lamp to be purchased was readily and intelligently made.

This suggests the best plan for the general purchaser. Let him determine, by test of the average product of different makers, the best make and type of lamp suitable for his service. Then let him buy the lamp thus selected, under specifications and guarantees, testing samples from each lot of lamps received, and holding the manufacturer closely to his guarantees.

DISCUSSION.

PROF. ARTHUR J. ROWLAND:—In most papers on incandescent lamps we find them treated from the standpoint of their candle-power, some peculiar or abnormal effects in them, their advantage as compared with other sorts of illuminants. Or, we listen to descriptions of special systems of lighting, or to accounts of instruments and apparatus made to test incandescent lamps. Here, in Mr. Willcox's paper, we have one giving a view of another side of the subject, the one on which we electrical people know too little. We do, indeed, know that some lamps prove unsatisfactory in this or that way, without being able to see or tell why they are so; that others are eminently satisfactory, but have no direct means of knowing whether this lot of lamps is good because they happened so, or whether

they represent a really steady process of manufacture. We know how, or think we know how, to test incandescent lamps; but need and welcome all the suggestions we can get from the people who make the lamps and who therefore know better than any one else what they can or cannot be expected to do.

To me the flashing of modern incandescent lamps has always been a most interesting process, both as to details of method and as regards the results procured. Here are the carbonized cellulose filaments, sooty in surface and sometimes of irregular resistance and spotty when current passes through them. They are put into gasoline vapor, a current turned on and the resistance drops as a tube of graphitic carbon deposits around each carbon filament until, the desired resistance having been reached, the circuit is automatically opened.

If the sooty surface filament had been put into a bulb and the combination made into an incandescent lamp, the life of the lamp would be short, the candle-power would rapidly drop, the efficiency be low (for the sooty surface is a good heat radiator) and the bulb be very hot. With the filament flashed, the candle-power and efficiency are well maintained through life, a high efficiency becomes possible, and the only disadvantages are the initial rise in candle-power and the readiness with which the filaments are strained by excessive voltage.

Every one should know that not only can one tell a graphite-covered filament by looking at it, as Mr. Willcox has explained, for its bright steely surface is very easily recognized, but one can tell whether there is much graphite on the filament or not by noting whether the filament is long for the voltage, candle-power and efficiency marked. The graphite deposit has a considerably lower specific resistance than that of the core ($\frac{1}{5}$ to $\frac{1}{7}$ as much), and, if much of it has been deposited, the filament must be long to get the required resistance. If there is plenty of graphite, we expect long life and maintained candle-power.

It has come to be the practice of lamp manufacturers to make tests of lamps to prove that they have the requisite

vacuum by connecting with a suitable induction coil and observing the absence of a glow in the lamps when they are being tested, and Mr. Willcox recommends the same test to users of lamps, to measure (in one respect) the value of lamps purchased. I suppose the manufacturers know how important the high vacuum is, but it is difficult for some of us to forget how some of the best lamps on the market a few years back (infringing lamps though they proved to be) were lamps in which the vacuum was low, an inert gas having been introduced at the last part of the exhausting process. I have some doubts, then, whether the spark-coil test may not work hardship on some real good lamps if the fact that they show a glow under the induction-coil test is to be taken as evidence that they are to be rejected. For high-voltage lamps in which the Edison effect is liable to be great, and so produce trouble at the leading-in wires, doubtless a high vacuum is essential, as distinguished by an absence of blue glow in the bulb when first burning or the absence of any glow under the induction-coil test.

Mr. Willcox tells us that the limits allowed for good 16-candle-power lamps in a specification for lamps need only be ½ candle-power each side of that and 1½ watts each side of the rated watts of the lamp. I have tried a good many lamps, and may, at least, express the opinion that limits as I have assigned them below are entirely satisfactory, and there are few lots of lamps taken from stock on the open market, of even the best makes, that will satisfactorily stand a closer test. These requirements are:

A 16-candle-power lamp is understood to be one which, when rotating on a vertical axis at 180 revolutions per minute, measures not less than 14·5 candle-power and not more than 17·5 candle-power as its mean horizontal candle-power.

A lamp is of satisfactory efficiency if it does not differ from its rating more than $\frac{2}{10}$ watt per candle-power.

I agree thoroughly with Mr. Willcox's statement that lamp tests are of small account unless a reasonably large number of lamps be put on test. It has been such common practice to put three lamps on a life test and draw con-

clusions from the performance of these that a test in which ten or more are taken looks very formidable. Certainly such a test is too much of an undertaking and too much expense is involved, too, to make it one which is likely to be made by the user of lamps in an ordinary isolated lighting plant. General tests, however, are not of much value to separate plants. The results of a test made on lamps on the circuits of one station will scarcely correspond with those made on another. The differences in regulation, the differences in actual average E.M.F. on the lamps will make quite a little difference in the results procured. I have examined into this by trial to some extent, and hope to find out more about it in the future. Results of general tests, then, show simply that certain lamps are good and certain ones are bad—scarcely that one make of lamps is 10 per cent. better than another because 10 per cent. more candle hours were had from it than from another.

A word regarding the fluctuations in candle-power values along candle-power curves. Not many months ago I would have attempted to prove in argument that after the initial rise, when the candle-power had really begun to drop, it would continue to do so, and any rise in candle-power observed was a sure indication of a false photometer reading. Now, I must acknowledge that there are sometimes curious "lumps" in the candle-power curve which must be due to real changes in the candle-power of lamps. But the man who is measuring candle-power had better beware of these as suspicious, especially if he has no rotating socket to use in making his tests. For that matter, a determination without a rotating socket cannot amount to much anyhow, and photometers in which they are absent are of little account. I have so often seen irregularities in candle-power curves really due to matters of small account seemingly, which were overlooked in making measurements on account of the inexperience of the observer, that I feel very confident in what I say. I very much question the advisability, too, of placing any confidence on results in candle-power measurements made by any person who has not devoted a great deal of time and attention to this sort of testing. No

test work of which I know is so liable to involve an unconscious personal error of large magnitude.

I wish Mr. Willcox had told us more of why the 80 per cent. limit is taken so commonly for the age limits of lamps and who proposed it. It seems as though it was a suggestion of a couple of years since, adopted at once by every one without question as to its being the proper limit. Of course, we know that the useful life of a lamp is controlled and so determined by its cost, the cost of the power it uses, and the decrease in candle-power per hour it burns. But obviously these are not fixed quantities, and it does not, therefore, appear why, when a 16 candle-power lamp gives only 12·8 candle-power, it is to be thrown away. I do not believe it is right to do so on the circuits of an isolated plant, however good practice it may be in central station work. As the candle-power drops, the total watts drop too, and although not in the same proportion, still it is cheaper to use these old lamps in corridors, in closets, in cellars, etc., than to throw them away.

I wish I could ask Mr. Willcox, too, whether he knows who originated the target diagram as a means of showing what lamps are and how a lot of lamps compare. I think the name is particularly happy, and the diagram (simple as it is) wonderfully expressive. I am very glad that the man who thought of it did not patent the idea; he was a public benefactor. Ever since I came upon it a year or so ago I have used it with a great deal of satisfaction.

One thing more. There has been a notable change in a few years past in the size of the bulbs used with lamps of a given candle-power. A few years back, for example, the 32 candle-power bulbs were about $3\frac{1}{2}$ inches in diameter and 6 inches long. Now we get them no larger than the bulbs of the 16 candle-power lamps used to be. Mr. Willcox tells us that European lamps are made still smaller than American. I wonder what influence the size of the bulb has on the life and maintained candle-power of an incandescent lamp. Certainly the small bulbs give to the lamps an added artistic merit, but one would like to know he is not paying too high a price for this. I am inclined to believe that small bulbs go with short life and rapid decline in candle-power.

PROF. W. M. STINE:—One of the most significant statements in Lieutenant Willcox's paper is the following: "It has taken years to bring home the real considerations (of the incandescent lamp) to electric lighting companies. These considerations are that a lamp is primarily designed and used to give light—that lighting companies are in the business of making and selling light, not power—and that the lamp is the chief essential of the lighting system."

It may be taken as a general law in the development of engineering practice in all lines that, at first, attention is mainly centered on mere accomplishment; and then, as the principles involved come to be better understood, they are examined in detail for efficiency of operation. However, in the case of the incandescent lamp it seems singular that such a statement as the author makes here should obtain; yet those who have had to do with the subject of incandescent lighting have repeatedly experienced its truth. In this line of operation the same remarks apply with equal force to switchboard and metering apparatus. It has required years of vigorous education of those operating and installing plants to recognize that a finely finished case may cover an exceedingly crude and ill-made instrument, and that the readings of instruments are valueless when the calibration of the scale is not known. Again, the same thing has occurred in the matter of suitable transformers, of the proper quality of carbons for arc lighting, and in varying degrees to almost every detail of installation for lighting and power.

The present paper is essentially educational in tone and argues that the leading manufacturers of lamps yet find that the most essential thing in a lighting installation—the final translating device—is so greatly overlooked. It is in this spirit, then, that the present discussion of the paper is presented.

The processes of manufacture have been reduced to such accuracy of details and to standard conditions, and cellulose filaments are made with sufficient uniformity in resistance and size, that further treatment on such account is unnecessary, in so far as treatment is needed for correction of imper-

fections in density, cross-section and length. It is important to note that flashing is no longer required for mechanical corrections. This clears the way, then, for understanding the necessity for plating all filaments with a layer of carbon deposited from a hydrocarbon vapor; the plating being needed for imparting certain necessary properties to the filament to insure proper economy in operation and length of life.

The surface of the cellulose filament, after carbonization, is somewhat rough and has a dull black appearance and its carbon is in an amorphous condition, and its properties in this state which affect the translation of electrical energy into heat and light energy must be examined.

The property by means of which heated carbon radiates its heat and light is termed emissivity, and for conciseness we may think of the emissivity being defined by the quantity of light and heat given off from the square millimeter of surface in the unit of time. The emissivity of a carbon filament is largely determined by the nature of the superficial layer, the interior of the filament having little influence on the emissivity. In general, filaments with a dull black surface show high emissivity for both light and heat.

Flashing consists in heating the filament electrically in an atmosphere of gasoline vapor; the heating of the filament decomposes the vapor in contact with its surface, and the carbon is deposited as a plating on the filament. The character of this plating is influenced by the density of the hydrocarbon atmosphere, and both the temperature at which it is deposited and the rate of deposition. The lower the density of the hydrocarbon vapor, the slower will be the rate of plating, and as a result the deposited surface will be both smooth and hard. And further, at a high temperature the carbon plating will become gray in color and very hard—graphitic, in short. The best conditions for plating are thus: a high temperature of the filament, and low density of the hydrocarbon atmosphere which will insure that the plating shall progress slowly. It may be considered that the plating under these conditions consists of hard, graphitic carbon.

Weber,* examining filaments which were untreated, or had a dull black surface, and comparing them with treated ones having bright gray and metallic-appearing surfaces, found that the emissivity of the two classes averaged the relation of 100 to 75·5. It is known that the emissivity of lampblack and graphite stands in the relation of 100 to 75; and the confirmation is clear that the gray coating of the filament is graphitic. The result, then, of flashing a filament under proper conditions is that its emitting surface becomes graphitic, which at a given temperature causes it to give out less light and heat; and because it thus loses less energy in a unit of time, it will require less energy to raise it to a given temperature and maintain it in that condition.

This treatment, however, does not result in any gain in the proportion of the light radiated in the total radiation; for both dull black filaments and those coated with graphite show the same proportions of light and heat radiations for the various temperatures at which the incandescent lamp is operated; or, in other words, the watts to the candle-power at any temperature will be the same for each class of filaments. For illustration, two filaments may be considered;† the one, *A*, having a dull black, or untreated surface, and the other, *B*, a treated, graphitic surface. The filament *A*, before flashing at a temperature T_1, gave 21 candles with 84 watts expended; and when flashed and again brought to this temperature T_1, it gave 15 candles with 60 watts. For a higher temperature T_2 the results were as given in the table:

Filaments.		Candles.	Watts.	Watts to the Candle.
Black	at temperature T_1	21	84	4
Gray		15	60	4
Black	at temperature T_2	28	90	3·22
Gray		21	68	3·24

The failure of an incandescent lamp to maintain its candle-power, especially marked after several hours' burning, is

* *Physical Review*, 1894, page 116.

† "The Incandescent Lamp," G. S. Ram, page 63.

very largely due to a change in the emissivity of its surface. Repeated heating of the filament may be considered to bring about gradual annealing of the graphitic layer with a tendency toward the condition of amorphous carbon. This would naturally increase the emissivity, a result which is known to occur. In one case Ram found the emissivity to have increased about 25 per cent.* The immediate effect of increasing the emissivity is that the temperature will be lowered; for if the amount of heat generated in the filament, or the watts supplied to it remained constant, while the filament cooled more rapidly, the temperature would fall. At the lowered temperature the proportion of light radiated to the total energy is greatly decreased; and though the total light and heat radiated at the lower temperature would be the same as before, the proportion of the light to the heat radiated is so much lessened that the lamp drops in candle-power and increases in the watts expended to the candle-power.

The two great factors governing the selection of incandescent lamps are: (1) the watts to the candle, and (2) the maintenance of the initial candle-power. The requirement to meet the first is low emissivity which will cause a filament to be operated at a high temperature to produce the initial candle-power; for at a high temperature (corresponding to bright, white light) the proportion of the light to the heat radiated is greatly increased, which amounts to the statement that a high efficiency is obtained. It has already been seen that when the flashing is properly done the filament will meet this requirement.

The failure to maintain the initial candle-power is usually explained by the evaporation of carbon, which decreases the cross-section of the filament and increases its resistance. While this does occur to some extent, it is only an inconsiderable factor in the case of well-made lamps. The droop in the candle-power curve is frequently already pronounced before the bulb becomes especially discolored and the filament can have lost much by evaporation. The main cause

* Reference cited, page 64.

at work is the increase in the emissivity of the surface; the graphitic plating slowly becomes amorphous carbon, the appearance of the filament in the meantime changing from a polished gray surface to a duller and rather black one, all brought about by a species of annealing.

When purchasing lamps, preference ought to be given to the filaments which have a bright gray and well-polished appearance, for such filaments will prove both efficient and long-lived when properly operated. The appearance alone is not a sufficient guide; the graphitic layer should have been deposited very slowly in a hydrocarbon atmosphere of very low density that the plating may have taken place at a reasonably high temperature. If the plating is done at the proper temperature and not too rapidly deposited, the annealing of the surface layer will take place more gradually, leading to better maintenance of the candle-power. It is generally understood that a lamp showing excellent maintenance of the candle-power is not one to show high efficiency, and that a lamp of high initial efficiency will soon lose in candle-power. It has now been shown that this is practically a question of the emissivity of the surface layer. In the lamp for maintained candle-power the flashing must be done slowly in fact, but at a lower temperature than is used for higher initial efficiency.

The most radical improvement in the incandescent lamp must result from a combination of these two features in one filament, and doubtless the manufacturers will presently learn to deposit a graphitic coating which will not readily anneal and increase in emissivity.

MR. F. W. WILLCOX:—In Professor Rowland's discussion of my paper he alludes to the lamps made some years ago with low vacuum through insertion of inert gas. Professor Rowland describes these lamps as some of the best in the market. In this respect he is in error, as these lamps, far from being the best in the market, were very unsatisfactory, so much so that the manufacturing of them was discontinued.

In view of this fact there is no occasion for the doubt he expresses as to the question whether a spark coil test may not work a hardship on real good lamps.

The limits referred to by Professor Rowland as given by me should be understood as average limits, and the limits mentioned in his requirements should be individual limits.

His comments on different results obtained from tests by various stations are in general true. It must be observed, however, that it is not necessary that tests made on different plants should agree. Any one station making a test on lamps simply wishes to find out the comparative differences between makes when tested on their circuits for candle-power performance. All the lamps on the test would be burned together and subject to the same fluctuations of voltage, and, therefore, the difference should indicate the approximate percentage of superiority and inferiority. A proper laboratory test to determine absolute differences between lamps should only be made, of course, under absolutely perfect regulation of voltage.

The 80 per cent. age limit of lamps was adopted as an agreed limit by the leading illuminating companies of the country.

The actual economy of a lamp starting at 3·1 watts per candle will change through a 20 per cent. loss of candle-power to 3·75 watts per candle, so it is evident that this limit is none too high considering the ratio of light given to power expended. It does not follow that it is necessarily cheaper to use old 16 candle-power lamps in corridors, cellars, etc., than to throw them away, as the cost of light can be reduced in many cases by using new 6 or 8 candle-power lamps in such locations, consuming less than one-half of the total wattage taken with the old 16 candle-power lamps.

There is and always has been too much of a tendency to attempt to use old lamps. The incandescent lamp has a certain period of useful service, beyond which it is useless. It is false economy to attempt to use it beyond this point. The cost of current during the period of lamp service is eight to ten times the value of a lamp, and the lamp, therefore, soon eats up its own value in current a number of times.

The tendency to hold on to old lamps and use them is

responsible more than anything else to-day for any poor quality that may exist in incandescent lighting service. Old incandescent lamps should be considered in the same category as old tomato cans or any other old waste truck to be broken up and discarded, and not continued in service because they continue to burn.

Regarding the target diagram, the idea of this was suggested by the writer to Mr. W. S. Howell, Secretary of the Association of Edison Illuminating Companies, and was first worked out and used by him in connection with the lamp tests of the Association of Edison Illuminating Companies.

The influence of the size of bulb on the life and maintained candle-power of incandescent lamps is an interesting topic.

There would be a definite difference in candle-power and life performance were the bulbs of lamps proportioned in size to the candle-power. This is not the case, however, the 24 candle-power bulb, for instance being the same size as the 16 candle-power. Better results in candle-power performance and freedom from blackening in same candle-power lamps are always possible with larger bulbs. This is shown in European type of lamp, which is made in a much smaller bulb than the American. This limits the candle-power performance of results to be given by these lamps, and even with everything else equal will always give inferior results than the larger of the American type of lamp.

I am particularly interested in Professor Stine's comments on the paper, especially as he seems to have struck the keynote of the discussion in regard to the use of lamps, namely, the difficulty of getting lighting companies to appreciate the real consideration of incandescent lamps, their light-giving qualities. He correctly analyzes the cause of this. It is surprising, however, how much ignorance and indifference still exist among the numerous central stations throughout the country, and particularly abroad on the Continent of Europe, where the electric lighting suffers from the total disregard of this feature of incandescent

lamps. Professor Stine speaks quite positively as to the cause of loss of candle-power in incandescent lamps, and it would be interesting to know on what he bases his theory. There are many rather novel and surprising things in this part of the discussion referring to the treatment of the filament and annealing process, and considerable experimental proof should be given before they could be accepted as final.

Mining and Metallurgical Section.

Stated Meeting, April 11, 1900.

RAILWAY BEARINGS: AN INVESTIGATION OF CAUSES OF HOT BOXES IN RAILWAY SERVICE, AND METHODS FOR THEIR PREVENTION.*

By Robert Job,
Chemist to the Philadelphia & Reading Railway Company, Reading, Pa.

I take pleasure in presenting herewith results of an investigation to determine causes of hot boxes in railway service due to defects in the bearings themselves, and methods for their prevention.

It is a fact, well known to those who have made a study of bearing metals, that physical condition and structure exert a marked influence upon the efficiency of the metal in service. Formerly great stress was laid upon the general chemical composition of the alloy, and comparatively little attention was paid to the effects of the different conditions of foundry practice, or to the relation between structure and efficiency. The natural results followed, and "hot boxes" became prevalent in railway practice, especially so when weights and speeds became materially increased. Attention was thus directed to the production of cool-running and durable bearings.

As a result of carefully-conducted service tests, the old

*A partial report on this subject appeared in the impression of the *American Engineer and Railway Journal* for February, 1900.

copper-tin alloy of seven to one was found to be inferior as a bearing metal, and the copper-tin-lead composition was gradually introduced, at first combined with phosphorus, and later with this element present in very small proportions, if at all, and then used only as a deoxidizing agent. Also, the efficiency in antifrictional qualities of a copper-tin-lead composition, other things being equal, was shown by Dr. Dudley to increase with the proportion of lead which was present, the amount being limited, owing to the necessity of maintaining a strength sufficient to support the load, and also a fairly high melting point in order to prevent fusion and running from the box if heating resulted. In the best practice not more than 15 per cent. was present, owing partly to the above reasons, and partly to the inability at that time to satisfactorily combine a larger proportion.

During the past few years greatly increased attention has been paid to the microscopic study of the metals, and the importance of this method of investigation is becoming clearly recognized in view of the results which are being obtained through its use. In the course of an investigation to determine the alloy most efficient for general railway use, we found it desirable to follow up this structure of bearing metals in order to note the influence of this as well as that of chemical composition upon durability in service.

To secure information, a large number of bearings which had run hot and had been removed from cars of different railroads while passing over the Philadelphia & Reading Railway were taken for test. Fractures were made to show the general physical character of the composition, sections for microscopic examination were removed, polished, etched, magnified as far as necessary to show the structure to best advantage, and photographed. Analyses were also carried on at the same time, especially in cases where marked segregation of the metal was found to exist, in order to determine whether this result was due simply to an attempt at the foundry to form an alloy in proportions which were physically impracticable, or whether it was an effect of improper foundry manipulation. The marked crystallization which was often found in these bearings was also investi-

gated in a similar manner. Also, in the majority of cases, test sections were cut from the bearings, and the tensile strength and elongation determined in order to find out whether in a given composition proper foundry practice would not be ensured by placing a limit upon the strength and ductility of the alloy.

Side by side with these tests a considerable number of alloys have been prepared in the foundry to check the accuracy of the deductions and to secure information as to the conditions of foundry practice necessary to give the greatest strength and ductility to the given composition, the objects throughout the investigation being, first, to determine the sources of excessive friction inherent in bearings prepared under widely differing conditions of foundry practice, then to find out by experimentation the practice by which such defects were produced, as well as the methods and manipulation necessary to insure the most efficient results, in order to establish in our foundries a thoroughly serviceable standard practice as free as possible from observed defects.

In the composition of the bearings a wide variation was naturally found, among others being the old copper-tin alloy of seven to one, and copper-zinc bearings running as high as 35 per cent. in zinc, an alloy which, by the way, had seldom been discarded owing to heating resulting from defects in the bearings themselves, but which showed evidence of exceedingly rapid wear; phosphor-bronzes were found in moderate amount, while most numerous of all—probably because most used—were the copper-tin-lead compositions, varying in their proportions considerably, but averaging from 10 to 15 per cent. of tin, with from 15 to 5 per cent. of lead, the balance being principally copper. In the majority of cases, however, the mere general composition was found to have caused but small part of the difficulty. The main causes were the following:

(1) Segregation of the metals.

(2) Coarse crystalline structure.

(3) Dross or oxidation products, and an excessive amount of enclosed gas in the metal.

In addition to these the lack of proper lubrication might be mentioned, though our investigation seems to show that a relatively small percentage of the bearings examined had been discarded owing solely to this cause.

Segregation has been found to be due in many cases to an attempt to alloy the metals in improper proportions, this being notably the case in some of the copper-tin-lead compositions in which an excessive proportion of lead had been introduced, with the ordinary practice, resulting in the liquation of a portion of the lead, and often also the separation of a part of the copper into "copper spots," thereby producing surfaces of relatively high heating capacity, and ultimately causing "hot boxes." *Fig. 3* represents a photomicrograph of a copper-tin-lead composition which had segregated owing to pouring too rapidly when at a high temperature. In this case a portion of the lead had separated out, and also a slight crystallization is seen, owing to the presence of a slight excess of silicon in the metal. *Fig. 12* represents a bearing which had been badly segregated owing to rapid pouring, and had run hot in service. The composition was as follows: Copper, 74·67; tin, 15·27; lead, 10·27. *Fig. 1* is a photograph showing upon one side the fracture of a badly segregated bearing with "copper spots," and upon the other that of a well-mixed and homogeneous composition taken at random from our daily output, the segregation in the one case being due partly to the presence of an excessive amount of lead in the brass, but mainly to rapid pouring at high temperature.

To a certain extent these segregations may be prevented even in a wrongly proportioned alloy simply by rapid chilling of the metal immediately after pouring, as for instance by the use of a cold iron mould. Such practice is, however, at the expense of the ductility of the metal, and causes a marked increase in brittleness with consequent rapid wear in service. High heating, combined with rapid pouring and feeding, is, as mentioned, a very frequent cause of segregation, since under such conditions the metal in the mould remains for a considerable time in a molten condition, and by chilling gradually is given the greatest possible chance

to solidify in definite natural alloys, throwing out whatever excess of metal may be present beyond these proportions, and thus resulting in segregation.

In actual service the effect of these segregations is readily understood, for it is evident that instead of an alloy of uniform hardness and heating capacity there is a mixture, some portions of which are relatively very hard, and others very soft, and this difference, combined with that occasioned by the varying heating capacity of the different portions, naturally localizes friction, and ultimately results in excessive heating. In a homogeneous alloy no such conditions exist, and although, as is true of some compositions, some of the metals may be present, at least in part, in mere mechanical mixture, and not as a definite alloy, yet the particles may be made so small that the friction throughout the bearing is practically uniform, and undue local heating is not liable to occur excepting through some outside agency. A fine-grained structure is obtained in these metals by means of comparatively slow pouring, the object being to have the metal in the mould remain in a fluid condition as short a time as possible, thus preventing any tendency towards segregation or settling out. Pouring at too slow a rate, on the other hand, tends to form "shot" in the bearing through the freezing of the metal before it has flowed completely into the mould. The proper rate of pouring can, however, be easily determined by careful experiment, and must be watched very closely in order to secure uniformly good results.

The coarsely crystalline structure which was often seen in these defective bearings was in some cases found to be due to the composition of the alloy, antimony especially tending in this direction. In many cases, however, it has been traced to the foundry practice, often being due to rapid pouring at high temperature. In *Fig. 10* we represent the condition of a crystalline bearing which had run hot in service. Crystallization was also often caused, as will be shown later on, by the presence of an excess of various materials which were originally added as deoxidizing agents.

The effects of this coarse crystallization upon the dura-

bility of the bearing are twofold. In the first place, increased local friction results in the same manner as in the case of segregated bearings, owing to the varying degrees of hardness and heating capacity of the constituents, and secondly, the ductility of the metal and the tensile strength are materially decreased. As the rapidity of wear with a given tensile strength has been proved by different experimenters to increase with brittleness, it becomes evident that the durability of one of these crystallized bearings in service is bound to be defective owing to an excessive rate of wear, even though the heating which would naturally result should not occur.

Fig. 9 represents a segregated copper-tin alloy containing about 80 per cent. of copper and about 0·1 per cent. of phosphorus, showing the crystalline structure of such composition, and it may be mentioned in passing that the old copper-tin alloy of seven to one, having a somewhat similar structure, and formerly much used as a railway bearing metal, is a notoriously rapidly heating composition, and is nôt often found to-day used for this purpose. *Fig. 2* is a photograph of one of these badly crystallized brasses together with one showing a homogeneous and fine-grained structure.

Another very common source of difficulty found in defective bearings was the presence of particles of dross or oxidized metal mechanically enclosed, and also of large amounts of occluded gas in the metal. In the former case a hard, cutting surface was presented to the journal, causing increased friction, and hence heating. The presence of occluded gas in excess also tended in the same direction by reducing the actual bearing surface of the brass, and thus materially increasing the pressure. Such metal was naturally found to be very brittle, and to have worn rapidly in service. In the foundry practice the presence of this enclosed matter is as injurious as in the bearings themselves, tending to cause sluggish pouring, unless the metal is heated to a very high temperature, in which case crystallization and segregation—as shown above—are liable to result unless the speed of pouring is very carefully regulated.

Lack of fluidity also tends to prevent the formation of sharp, clean castings.

Fig. 6 represents dross mechanically enclosed in a copper-tin-lead composition, and *Figs. 7* and *8* show this appearance of the metal when containing an excess of occluded gas, and show clearly the loss of bearing surface which may result from such porous condition.

In ordinary practice the foundrymen, if left to their own devices, avoid sluggishness of the metal by simple heating until sufficient "life" has been given. If the metal does not contain any appreciable amount of dissolved gases or oxidation products, such practice is perfectly correct. Unfortunately, however, the bearing metals in general retain obstinately a considerable amount of gas which is bound to cause sluggishness unless removed, and failure to effect this renders high heating necessary to give proper fluidity, and as in most foundries the piecework system is in vogue, the main object of the men is to empty the metal into the flasks in the shortest possible time. Thus we have two elements combined, high heating and rapid pouring, which, as has been explained, are almost certain forerunners of hot boxes, owing to the segregation which generally results.

Sluggishness can be entirely prevented with a minimum amount of heat by simply removing these dissolved gases and oxidation products from the metal, and this can be effected by the use of any good deoxidizing material. It is, for instance, a matter of common observation that when a small amount of phosphorus is introduced into a pot of molten metal a marked increase in fluidity results, and upon microscopic examination of castings made before and after the addition, the structure of the latter will be found much the denser, and, as a result of this, both strength and ductility will be found to have increased considerably. Phosphor-bronze is, perhaps, the best-known metal of this class, and is noted for its fluidity in the foundry and density of structure owing to thorough deoxidation of the metal.

The wearing properties and strength of such metal have been found by different observers to be much greater than those of a metal of the same approximate composition but

not deoxidized. Unfortunately, however, in the phosphor-bronzes the attempt has been made to effect what may be termed "cumulative deoxidation," or, in other words, to store up deoxidizing material in the metal sufficient to remove oxidation products which may form upon subsequent remeltings. This effect, however, does not seem to result to appreciable extent, but, instead, a network of crystalline salts of the various metals is formed, and upon repeated remeltings this proportion of oxidation products gradually increases until finally the condition of the metal as a bearing is worse than if the deoxidation had never been attempted. *Fig. 4* represents the structure of a bearing which contained an excess of phosphorus, and shows the appearance of structures which is often found, and renders evident why such excess should be carefully avoided in the most efficient bearing metal. Phosphorus has been mentioned in this connection simply as an exponent of a general class, but the same may be said of any other substance which combines with the bases present to form salts. Excess of silicon, for instance, results in the crystallization shown in *Figs. 3* and *5*.

Turning now to what may be termed basic deoxidizers, or metals like zinc or sodium, which combine readily under the conditions of the foundry with whatever oxidation products may be present in the metal. The action of zinc as an aid in producing sound castings has been long known, and in 1892 Dr. Dudley pointed out that not more than between 1 and 2 per cent. should be added to the molten metal, the reason of this being that sufficient oxygen and oxidation products are usually present to combine with the greatest part of that quantity, forming oxide of zinc, which rises to the surface or passes off as a fume, leaving but little of the metal itself to act as a weakener. The effect of metallic sodium in small amount is similar to that of zinc, excepting that the action is much more energetic, and hence but a very small quantity is required to effect the change. Excess of these bases appears not to detract in any way from the antifrictional qualities of the bearing; they do, however, act to a marked extent as weakeners,

decreasing both tensile strength or ability to carry loads, and elongation or wearing quality.

In any large railway foundry considerable quantities of bearings discarded through one cause or another from cars of foreign roads are received in the scrap heap. Such bearings may contain a good deal of "yellow brass," that is, metal containing a considerable proportion of zinc. If much of such brass is added to the pot, a considerable proportion of zinc is introduced, and comparatively rapid wearing in service is certain to result. The best practice in such cases is, perhaps, to set aside such yellow bearings, and to add but one of them to a pot of metal, or just enough to correspond to the 1 to 2 per cent. of zinc desired, omitting then the addition of spelter entirely. By this means the good results of the deoxidation by means of the zinc may be obtained without retaining sufficient excess to produce brittleness. Zinc of itself does not, however, effect complete deoxidation, as may be shown by observing the increased fluidity in a pot of metal upon adding a small amount of silicon or phosphorus after deoxidation with the zinc, and noting the oxidation products which subsequently rise to the surface. The density of the metal also will be found, upon test, to have increased after the addition. In our own practice we prefer the use of silicon in very small proportion after the addition of zinc in the form of spelter, or as yellow brass. By this means a very strong close-grained and ductile metal is obtained at a minimum cost. We find it necessary to regulate the amount of silicon very carefully in order to avoid the partial crystallization which, as has been shown, would otherwise result. It is easy, however, to determine the amount needed by experiment, adding a definite quantity of silicon to the melted metal after partial deoxidation with about 1 per cent. of zinc, stirring thoroughly, and pouring at once. A section is cut from a casting, and polished, etched and magnified. If an excess of silicon is present the crystalline appearance will be seen, as in *Figs. 3* and *5*. If this is the case, the amount of silicon should be reduced in the next batch, and a section again examined, this being continued until but a bare trace

of silicon is found in excess, thus ensuring almost entire absence of crystallization due to this cause. In our practice we have found that the amount of the deoxidizer required in the different lots of scrap is fairly uniform, and we therefore merely add to each pot the amount found necessary upon an average, checking up the quality by taking bearings at random from the daily output, a practice which we consider indispensable in maintaining efficiency among the workmen. Arsenic is sometimes used to effect deoxidation, but gives no better results than other deoxidizers, and should not be tolerated in the foundry on account of its poisonous properties.

Turning now to the influence of the above-mentioned defects upon the tensile strength and elongation of the bearings examined. Dross or oxidation products are simply elements of weakness, and thus reduce both tensile strength and elongation. Coarse crystallization and segregation both tend in the same direction. With the former, the faces of the crystals form the surfaces of least resistance, and thus facilitate fracture and lessen ductility, while in the segregated bearing the different portions of the metal vary in tensile strength and elongation, so that the section tears apart under a comparatively low stress. Excess of deoxidizers also acts in a similar manner, and the result is especially marked in case of excess of zinc or of sodium, ensuring comparatively rapid wear in service. A test section taken from the bearing represented by *Fig. 4* showed a tensile strength of only 10,500 pounds per square inch, with an elongation of only 4 per cent. in a 2-inch section. A bearing of the same composition if properly prepared in the foundry and free from crystallization would have a tensile strength of about 25,000 pounds per square inch, and an elongation of about 13 per cent. when the test sections were taken from the bearing in a similar manner.

In the porous brasses we naturally found the same lack of strength and ductility owing to the deficiency in the amount of metal present in a given section. For example, the bearing represented by *Fig. 7* showed a tensile strength of 15,000 pounds per square inch, with an elongation of only

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Fig. 1.

Fig. 2.

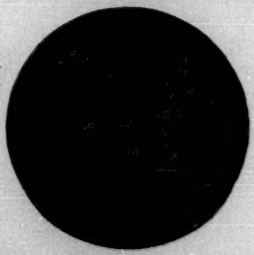

Fig. 3.

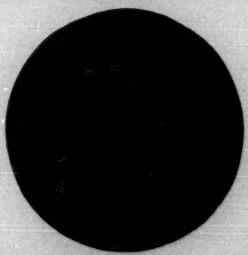

Fig. 4.

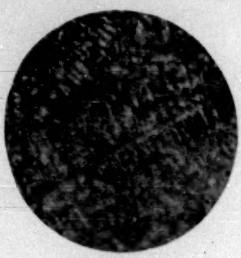

Fig. 5.

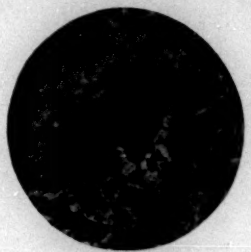

Fig. 6.

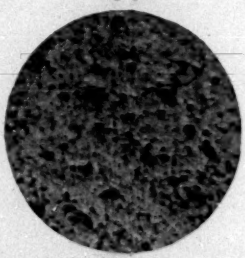

Fig. 7.

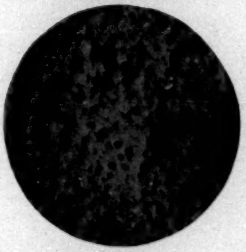

Fig. 8.

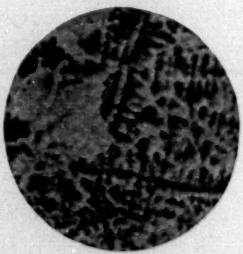

Fig. 9.

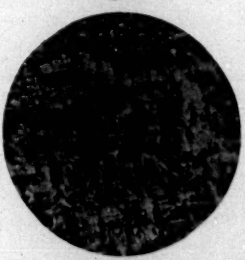

Fig. 10.

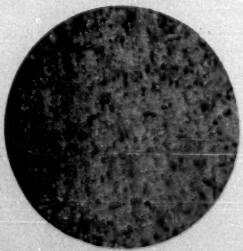

Fig. 11.

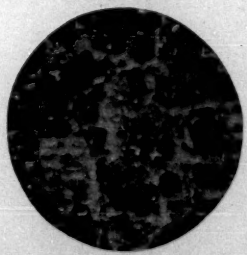

Fig. 12.

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6 per cent. *Fig. 8* showed a tensile strength of 18,700 pounds per square inch, with 7 per cent. elongation. Thus we see that the influence of the various defects is clearly shown when metal of a known composition is subjected to tensile tests, and it becomes possible to hold the foundry up to a high grade of excellence by this comparatively simple means with analytical and microscopic work as a basis.

Objection may, perhaps, be made that it appears rather arbitrary to place limits upon tensile strength and elongation in bearings, and that, after all, in practical service it is merely necessary to have, with a proper composition, a fairly strong homogeneous material to obtain good results. In reply, we will merely state that as a result of very carefully conducted service tests made by placing bearings of practically the same composition, but differing widely in both tensile strength and elongation, upon opposite ends of the same axles, we have invariably found that increase of strength and ductility meant an increased life to the bearings in service and a lessening of wear, our results in this respect being in accordance with the deductions given by Dr. Dudley in 1892 before the Franklin Institute. As an instance of difference in efficiency due to these causes, we may cite a service test in which eight bearings each, of two copper-tin-lead compositions, were placed under tenders of fast passenger locomotives, one bearing of each kind being placed upon an end of each axle. All the bearings were of practically the same composition, but the one set showed a tensile strength of about 16,500 pounds per square inch, with an elongation of about 6 per cent., while the other had a strength of about 24,000 pounds per square inch, with an elongation of about 13 per cent. This marked difference was due simply to the fact that in the one case the metal was porous, about as shown in *Fig. 7*, while the other was thoroughly deoxidized, and was close-grained and homogeneous, similar in structure to *Fig. 11*. From time to time these bearings were removed and weighed, and the end wear measured. As a final result, it was found that the more brittle set had worn 35 per cent. more rapidly than the others. The results of similar tests, also, have been in

line with the above. Therefore it becomes evident that increased ductility and strength in the bearing of given composition means, as stated, an increased life for the bearings in service, and, as relatively high ductility necessitates also freedom from the defects which we have mentioned, it is evident that the chances of cool running are proportionately greater. These qualities are therefore not merely of theoretical interest, but have an intensely practical value, and have a marked influence upon the success and economy of railway service.

Regarding the preparation of the sections for microscopic study, we have found it desirable to cut them from the center of the bearing, filing and polishing after the usual methods, and finally etching with an approximately decinormal solution of iodine in potassium iodide, the time of etching being usually about one minute. This etching gives very satisfactory results in many cases, though in some etching with dilute chromic or nitric acid has shown the structure to better advantage. In ordinary work we have found that magnification to about thirty diameters is sufficient.

DESCRIPTION OF PLATES.

FIG. 1.—Fine-grained and homogeneous. P. & R. Ry. standard. Crystallized by defective foundry practice (copper-tin-lead bearings).

FIG. 2.—Segregations. Fine-grained, homogeneous bearing. P. & R. Ry. standard (copper-tin-lead bearings).

FIG. 3.—Segregation; also silicide crystallization (copper-tin-lead bearing).

FIG. 4.—Crystallization due to phosphides (copper-tin-lead bearing).

FIG. 5.—Silicide crystallization (copper-tin-lead bearing).

FIG. 6.—Enclosed dross (copper-tin-lead bearing).

FIG. 7.—Enclosed gas (copper-tin-lead bearing).

FIG. 8.—Enclosed gas (copper-tin-lead bearing).

FIG. 9.—Segregation; also phosphorus crystallization (copper, 80 per cent.; tin, 19·97 per cent.; phosphorus, 17 per cent.).

FIG. 10.—Crystallization (copper-tin-lead bearing).

FIG. 11.—Close-grained and homogeneous (copper-tin-lead bearing).

FIG. 12.—Segregation due to rapid pouring (copper-tin-lead bearing).

THE FRANKLIN INSTITUTE.

Stated Meeting, Wednesday, April 18, 1900.

RECENT PROGRESS IN THE ALUMINIUM INDUSTRY.

By Prof. Joseph W. Richards,
Lehigh University, Member of the Institute.

Professor Richards spoke in substance as follows:

It is not yet seventy-five years since aluminium was first isolated as a metallic powder, and not yet fifty years since it made its appearance as a true solid metal, while until fifteen years ago its price was counted in dollars per pound, and it was used only for articles of luxury or for purposes where lightness was a desideratum and expense was not considered. From 1884 to 1891 several new processes of production followed each other, reducing the price nearly 50 per cent. each year and causing the output of metal to increase nearly 100 per cent. each year, until with the present decade aluminium became a metal of every-day life, for it began to compete with such ordinary metals as German-silver, britannia, pewter, bronze, copper and even brass. To-day sees this new metal firmly established among the every-day metals, known to and used by the general public, and destined to ever-increasing usefulness until its only rival will be iron and steel.

My further remarks will concern only *recent* advances; and in the line of pure metallurgy, that is, reduction and refining, there is little to chronicle. The process of reduction has certainly been somewhat improved in details, but in principle it is the same as the Hall process of ten years ago. The operators of the process are naturally averse to publishing the details of their operations, and the outside public is vouchsafed information only upon the properties and utilization of the metal. About all there is to be said is that during the last few years all the items of expense of the process have been gradually notched down—bauxite is

being mined and prepared better and more cheaply; its conversion into alumina is probably improved; electrolytic carbons are being made cheaper and more durable; electric power is being obtained more cheaply, and, finally, the doubling and doubling again of the size of the works has reduced correspondingly the cost of superintendence and office expenses. These, and probably several other items of saving, have altogether reduced the cost price of aluminium to probably about 20 cents per pound, while its selling price is slightly over 30 cents in the United States and 25 cents abroad.

I could wish to be free to give more information on these metallurgical details, but since that is denied, I will pass on to the various uses of aluminium which have recently appeared.

Here is a small box containing a dozen aluminium thimbles, which was sold in the largest store in this city, this week, for 5 cents. This furnishes me a good text to talk about the displacement of other common metals by aluminium. These dozen thimbles weigh less than ½ an ounce, and the aluminium in them cost the manufacturer just 1 cent. If he had made them of common brass, they would have weighed 1½ ounces, and the metal in them have cost 1¾ cents, which is an increased cost of metal of 75 per cent. Or, stating it another way, to manufacture $1,000 worth (selling price) of thimbles, the manufacturer would have to buy to make them (allowing 25 per cent. for waste clippings) $250 worth of sheet aluminium or $437.50 worth of sheet brass. The general public considers brass as a cheap metal, and such facts as the above are rather startling when first grasped.

Coming to the city in the train to-day, I estimated the amount of brass fittings on one railway car as about 300 pounds. Without exception, they were replaceable by light aluminium alloy, which, fully as strong, would weigh only 100 pounds and cost only two-thirds as much. The difference in cost would probably amount to $20 per car, in favor of aluminium, while the saving in dead-weight hauled would be more than the average weight of one passenger per car.

Such instances as the above could be multiplied *ad libitum*, but these suffice to prove the point, little apprehended by the general public, that for almost every practical purpose aluminium is cheaper than all the common metals excepting zinc, lead and iron. Brass, tin, copper, are of approximately the same specific gravity, and in comparing their costs we usually think only of their relative cost per pound; but aluminium is entirely in another class. It takes only one-third of a pound of aluminium to take the place of one pound of these metals, and the proper basis of comparison here is to compare the price of one-third of a pound of aluminium with that of one pound of brass, etc. The comparison, therefore, stands as follows:

One-third pound of aluminium	$0 11
One " " brass	15
" " " copper	17
" " " tin	30

The next great improvement, after that of the fall in price, has been in the successful manufacture of light, strong alloys. This has been a subject at which metallurgists have worked hard and long, and their labors are bearing fruit in abundance. Pure aluminium has many resemblances to pure copper. Take away the red color of copper, and its softness, malleability, toughness, silky fibrous fracture are almost exactly duplicated by aluminium; but they are both soft, rather weak, metals. Five per cent. of aluminium, silicon or manganese or 30 per cent. of zinc added to copper make famously strong bronze or brass. Similarly, 5 per cent. of copper, nickel or manganese, or 30 per cent. of zinc, added to aluminium, make strong metals as rigid as bronze yet only one-third as heavy. Such light, strong, good casting and machining alloys have an extremely large field of usefulness, and will receive a very large application in the near future. It would be possible for me to consume half of the time at our disposal this evening telling alone of the various strong, light alloys which have approved themselves in very recent years; but, as an illustration, I will mention the alloy made by the Delaware Metal Refinery, of this city, and which is one of the best. It is a hard white

alloy, specific gravity 3·1, melts clean, runs fluid, makes beautifully sharp and perfect castings, turns and machines like the finest brass, polishes well, and, to conclude, is fully as rigid and strong as gun-metal or the best of the ordinary bronzes. I do not enumerate this catalogue of virtues merely from my own knowledge of the alloy, but could substantiate it from the experience of Philadelphia firms who are using it regularly and are quite enthusiastic over its possibilities. This alloy is principally of aluminium and zinc, and sells at the same price per pound as pure aluminium. The field of application of light alloys with such properties to light-running machinery, portable apparatus, vehicles, instruments, etc., is almost immeasurable, and the next few years will see its use very general for such and similar purposes.

The use of aluminium for culinary utensils is extending steadily, as their merits become better known. A brief statement of what they are for this purpose is that they possess all the advantages of copper utensils, with none of their disadvantages. The first aluminium utensils put on the market, ten years ago, were generally too lightly made, and were consequently easily dented and bent out of shape. The manufacturers have learned by experience, and the ware now being sold is fully as durable as the best copper ware. An aluminium kettle in my father's house has been on the stove constantly for seven years, boiling Schuylkill water, and is apparently uninjured and unworn. The inside has a brownish adherent skin of oxide which seems to be continuous and to efficiently protect the metal beneath from further oxidation. It bids fair to become an heirloom in the family. [In reply to a question: "The aluminium goods need only as much attention as ordinary tin ware to keep them bright and clean. Bath-brick dust, such as is used for polishing knives, is as good a scourer as can be used on them."]

There are at present a full dozen firms engaged in manufacturing this culinary ware, and it is now so generally known that it was unnecessary for me to display any here as a novelty. This small "bonbonnière," made by Hill,

Whitney & Co., of Waltham, Mass., and modelled after the famous silver porringer hammered out by Paul Revere, is interesting as to its shape, as well as showing the beautiful finish, inside and out, which can be given aluminium ware.

As a distinct novelty in aluminium goods may be mentioned the beautiful ware being made by the native metal-workers in the bazaars and industrial school at Madras, under the leadership of Mr. Chatterton. These native workmen are probably the most skilful metal-workers in the world, and their work is principally confined to steel arms, silver ornaments and copper and brass utensils. The fact that aluminium sheet blanks can now be purchased cheaper than similar sized blanks of copper or brass has given the opportunity to introduce the working of aluminium. The natives have easily mastered the peculiarities of the new metal, and take most kindly to it. The native Indian troops are largely supplied with aluminium ware, and it is coming into favor in all castes, from the lowest to the highest, on account of its lightness and cleanliness, whilst costing no more than copper or brass utensils.

[There were here shown on the screen a number of photographs of the bazaar workshops and their ware, loaned for the lecture by the *Aluminium World*, of New York. The scenes were most realistic, and, judging from the photographs, the ware is equal in construction and superior in artistic finish to any other aluminium ware made anywhere.]

There are upon this table many small articles and novelties in aluminium, loaned by Mr. Mertz, of your city. It would be useless for me even to attempt to name all the various goods which are now being made of aluminium, in which its lightness and prettiness are much in evidence. The toilet goods and pocket articles are especially in favor, and aluminium combs are being made by tens of thousands, and consuming a generous share of all the aluminium sheet made. An equally large use is for fruit-jar caps, for which aluminium is superseding zinc, although more expensive, because of its harmlessness.

In the artistic branch of *lithographic printing* aluminium is rapidly winning an important place. Nearly two years

ago, speaking in this hall about the progress of aluminium industries in Europe, I spoke of the establishment I had visited at Mainz, which printed altogether from aluminium plates. The process was then quite new, but since that time about thirty firms in the United States alone have taken up the aluminium plate printing, and are using it regularly, while the number in Europe is probably forty or fifty. Here is a trade catalogue printed by the Sackett & Wilhelms Company, of New York, which is probably as fine a specimen of commercial color work as was ever printed, and this firm prints exclusively from aluminium plates. The printing is entirely surface work, and is being generally done on cylinder presses instead of flat-bed machines, the aluminium sheets being bent onto the cylinder, and thus allowing of fast running. This is, indeed, a most promising infant industry, which cannot but grow to large proportions, seeing the advantages of aluminium plates over lithographic stone.

Electric conductors can now be laid more cheaply in aluminium than in copper. This is indeed a startling statement when first heard, for almost every one is wont to consider copper as the metal *par excellence* for conductors. But, pure aluminium has over 60 per cent. the conductivity of pure copper, and is fully as strong and resistant to atmospheric influences. It is therefore only necessary to take an aluminium wire one-fourth as large again in diameter as a copper wire (giving a little over 50 per cent. more section) to get equal conductivity. Such a wire weighs one-half as much as the copper wire it replaces, and costs only two-thirds as much. Long-distance transmission lines and trolley-line feed wires are being put in in aluminium as fast as the makers can supply the metal. Over 500 tons of aluminium were used for this purpose last year, and probably double as much will be used this year. As 500 tons supplants 1,000 tons of copper, it will not be long before the copper industry will begin to feel the competition of aluminium, but will probably be unable to meet it. This one use of aluminium promises in the near future to consume its thousands of tons a year. What a contrast to the

industry fifteen years ago, when two and one-half tons of aluminium was the output of the whole world in one year!

The samples of aluminium cables before you were kindly sent by the Pittsburgh Reduction Company, which has been foremost in developing this use of aluminium.

It is now necessary for me to rapidly bring my remarks to a close, and to leave unnoticed many interesting items which might be mentioned did time permit. I will close by referring to *powdered* aluminium and the many applications it is receiving. Aluminium can be rolled out to $\frac{1}{2000}$ of an inch in thickness, and then beaten out to $\frac{1}{40000}$ or even $\frac{1}{70000}$ of an inch. As thin sheet it has found some application in place of cardboard, for business cards, etc., but as leaf it has entirely superseded silver leaf in decorating. This leaf can, moreover, be ground to powder, and in this condition is used by printers for silvery printing, and as a paint. For the latter use it is simply mixed with a varnish, like ordinary bronzing powders, and has already proven its beauty and utility on Uncle Sam's letter-boxes. Every one here has had the opportunity of seeing this use and judging for himself of its practicability. It is to be hoped that the Public Buildings Commission of your city will not overlook this material when considering the painting or refreshing of the metal work on the City Hall tower. It is not likely that a more suitable, durable or beautiful covering can be obtained than this would give, whilst the cost would certainly be moderate.

The powdered aluminium has recently received an extremely interesting metallurgical application, in the reduction of refractory metallic oxides to the metallic state. Over forty years ago Tissier proved that aluminium energetically reduces some metallic oxides. He mixed the metallic oxide with aluminium powder, heated it in a furnace, and generally succeeded in reducing the oxide to metal and, in some cases, reducing the furnace to ruins. Our esteemed Secretary, Dr. Wahl, with Dr. Greene, made use of the same energetic reducing power of aluminium to produce carbonless metals, by incorporating with the finely-divided metallic oxide the needful quantity of granu-

lated aluminium and reducing the mixture with the aid of heat, in magnesia-lined crucibles, adding a certain quantity of flux to this mixture to facilitate the reduction. They found this process to be specially applicable to the production of carbonless manganese and chromium of a high grade of purity. This is indeed a practicable method of operating the reaction under control.

A further improvement is the method of Goldschmidt, of Essen, Germany, who mixes the metallic oxide with powdered or granulated aluminium and ignites the cold mixture in a cold crucible. The heat thus generated is sufficient to melt the reduced metal and even the resulting alumina, and the danger of explosion is very small. To ignite the mixture, a small hole is scooped in its upper surface, into which is put a mixture of barium peroxide and aluminium powder, which is relatively easy to ignite. A strip of magnesium ribbon or flash-light paper is stuck into this mixture, and lit by a match. The magnesium sets the peroxide mixture off, and this starts the oxide mixture reacting next to it, and the heat thus spreads through the whole mass. In five to ten seconds the entire contents have reacted; the generation of heat is so rapid that the crucible does not become warm outside for some minutes, and is so intense that it is unbearable to the eye, and is probably between 2,500° and 3,000° centigrade. In operating on a large scale, a small amount of the powder is first ignited in the crucible, then more is continually added and the reaction kept up until the crucible is full. Then the melted alumina slag is poured off and the melted metal beneath poured out. The method is applicable to reducing to metal almost all metallic oxides, except those of magnesium, the alkaline earths and earths, and has been applied to the more expensive metals which are ordinarily considered as difficult to reduce, such as manganese, chromium, titanium, tungsten, molybdenum, vanadium, uranium, boron, etc. In some cases the ferro-alloys are made, which are an easier form to introduce the metals into steel, melting easier and diffusing quicker in the steel. At Krupp's works, at Essen, many such alloys are made for use in armor-plate steel, and a

similar class of alloys is being made here in Philadelphia, probably by the same method.

[A mixture of 8 ounces of green chromium oxide with 4 ounces of powdered aluminium was ignited by the lecturer, in the manner described. The heat developed in the crucible was intense, while yet it was cool enough outside to handle, and there was obtained a slag of melted alumina containing buttons of melted metallic chromium. The theoretical amount of the reducing agent in this case was 1 pound of aluminium, in powder or granulated form, to produce 1 pound of chromium. Granulated aluminium costs at present about 40 cents per pound; the powder, $1.25.]

Stated Meeting, April 25, 1899.

ELECTROMAGNETIC MECHANISM, WITH SPECIAL REFERENCE TO TELEGRAPHIC WORK.

BY R. A. FESSENDEN.

INTRODUCTION.

In designing electromagnetic mechanism, we should take as our motto "*cherchez l'erg*," and, having found the way the energy is distributed, we should always keep it in view. It is on these lines that I have written the present paper, and, as we shall see, this method leads to several very simple and useful rules.

As regards the nomenclature used, I have taken the units adopted by the American Institute of Electrical Engineers; *i. e.*,

P = Webers = number of lines of magnetic induction.
G = Gilberts = difference of magnetic potential.
N = Oersteds = magnetic reluctance,

the defining equations being

$$P = \frac{G}{N} \text{ and } G = 4\pi n I,$$

where n is the number of magnetizing turns, and I the current in them, all units being in the absolute electromagnetic system.

Also I have used the terminations -ance or -ion to signify the integral of the quantity and the terminations -ivity or -ibility to signify the intensity of the quantity, or the differential of the quantity with respect to some other quantity, thus:

B = Weberivity = flux per square centimeter.
H = Gilberivity = drop of magnetic potential per centimeter.
ν = Oerstedivity or reluctivity = specific reluctance.
μ = Permeability = reciprocal of reluctivity.
E = Voltage = difference of electrical potential.
F = Voltivity = drop of electric potential per centimeter.

Since, as will be seen, we can treat the subject more easily by dividing the flux into two parts, one due to the ether, which we will call the extrinsic flux, and the other due to the presence of iron or other material, which we will call the intrinsic flux, we have the following definitions:

P_i = Intrinsic flux.
B_i Intrinsic flux per square centimeter.
N_i Intrinsic reluctance.
ν_i Intrinsic reluctivity.
Q Electrostatic induction = lines of electrostatic flux.
D Electrostatic inductivity = electrostatic flux per square centimeter.

The upright capitals, Q and P, are used to denote quantity of electricity and magnetism, respectively.

It will be noted that I have followed, so far as possible, general usage and the recommendations of the American Institute of Electrical Engineers. It is extremely unfortunate that the theoretical men are perpetually making what they call "practical units," which they for some reason or other suppose are of great benefit to practicians. Thus, when the meter and gram were established, the system taken was the decimal one, and we were cut off finally from the very much preferable duodecimal one, whilst, had the duodecimal one been taken, it might finally have swamped out the decimal system entirely, to our great benefit and gain. Then, when the electrical units were fixed, out of

pity for the practical men the volt was taken as 10^8 absolute units, the ampère as 10^{-1} units, the ohm as 10^9 units, the farad as 10^{-9}, and so on, thus introducing endless confusion and failing in the very object for which all the trouble was made, for at present there is no question but that the volt is too small for practical work and 10^9 units would be better. If the volt, ampère and ohm were taken as the absolute units, the practical units would be the ampère, begohm and begavolt, names just as convenient as ampère, coulomb and farad. It is greatly to be desired that the theoretical men should leave off making any more units which they fancy will be convenient for practical men, and that they will stick to absolute units.

What the practical man wants is this (and I speak from a quite considerable practical experience, and acquaintance with other practical men):

(1) A system in which there are no so-called practical units, but all the units are absolute.

(2) A system of prefixes to denote the power of ten by which the absolute unit is multiplied, as suggested by Kennelly and Houston. Thus, begohm would represent 10^9 units of resistance, and would correspond to our so-called practical unit, the present ohm. Begohm is as easy to say as coulomb.

This system would have the immense advantage that it would not be confusing by necessitating, as the present system does, the introduction of all sorts of coëfficients when we change from one class of work to another. It appears to the writer to be supremely ridiculous to argue in favor of the C. G. S. system because it gets rid of obnoxious coëfficients in changing from, say, gravitational to inertial problems, and then to go and introduce other unnecessary coëfficients, in a much worse form (since it is easier to remember a string of three or four figures than to remember whether a thing is to be multiplied by 10^{-1} or 10^7 or 10^{-15} or 10^9 or 10^8).

Again, no units *can* be practical units, as conditions change so much with time and with the kind of work. A micro-farad is too large for use in telephone work, where

we often specify capacities in terms of tenths or hundredths of microfarads. But in power transmission by the single-phase system we often deal with capacity effects in alternating motors measured by thousands of microfarads. How much better it would have been to have chosen the farad as the absolute unit and let the telephone engineer speak of three hexfarads instead of having first to call it three one-hundredths of a microfarad and then to multiply by some forsaken coefficient. Similarly the transmission engineer would speak of three trifarads instead of 3,000 microfarads.

(3) One name, with different prefixes and suffixes for all terms connected with each single unit. At present the whole system is in the greatest confusion. As an aid to a comprehension of the existing state of affairs, the following extract from one of the works of a well-known mathematician (though not of itself mathematical in character) is given:

"You are sad," the Knight said in an anxious tone, "let me sing a song to comfort you."

"Is it very long?" Alice asked, for she had had a good deal of poetry that day.

"It's long," said the Knight, "but it's very, very beautiful. Every one that hears me sing it—either it brings the *tears* into their eyes, or else—"

"Or else what?" said Alice, for the Knight made a sudden pause.

"Or else it doesn't, you know. The name of the song is called 'Haddock's Eyes.'"

"Oh, that's the name of the song, is it?" Alice asked, trying to feel interested.

"No, you don't understand," the Knight said, looking a little vexed. "That is what the name is *called*. The name really is 'The Aged, Aged Man.'"

"Then I ought to have said 'That's what the song is called,'" Alice corrected herself.

"No, you oughtn't; that's quite another thing. The song is *called* 'Ways and Means;' but that's only what it's called, you know."

"Well, what *is* the song then?" said Alice, who was by this time completely bewildered.

"I was coming to that," the Knight said. "The song really is 'A Sitting on a Gate,' and the tune's my own invention."

The following dialogue, which can hardly be called imaginary, will now be more readily appreciated:

Electrical Unit Maker.—(Showing one volt cell to man who wants to be an electrical engineer) "This cell gives exactly one unit of Electromotive Force."

Student.—"Why was that name given to the quantity?"

E. U. M.—"I perceive that you misunderstand me; that is not its name, it is what it is called. Its real name is the Volt."

S.—"I beg your pardon; why is it called by the title Electromotive Force?"

E. U. M.—"Because it is not a force and has no immediate connection with motion, that being determined by its space differential."

S.—"Well, if that is what it is—"

E. U. M.—"Permit me to interrupt you. It *isn't*. It really *is* the unit difference of electrical potential. It is defined as the unit difference of electrical potential."

S.—"Ah, now I understand. You explained potential very fully to me yesterday. It is equivalent to electrical energy, then, isn't it?"

E. U. M.—"Not at all, not at all; you misconceive me entirely. It is true that we generally connect the idea of energy with the word potential, but in this case we use it in a special way. It really *is* only *one factor* of energy, and to get the electrical energy you must multiply it by another term, quantity of electricity."

S.—"You will excuse me for a moment, I am a little dazed. As I understand it, then, this unit—"

E. U. M.—"You must be very careful. There are three units. This is not the real fundamental unit. That is only one one hundred millionth of the volt. The volt was chosen this size for your especial convenience."

S.—"O Lord!" (*after a pause*) "then this other term which I see, magnetomotive force, is that also so called because it is not a force and has nothing to do with motion?"

E. U. M.—"Exactly."

S.—"But, from the definition of unit current, it certainly seems as if there must be some tendency for a magnet to move round a wire carrying a current, in the direction of the magnetomotive force."

E. U. M.—"Not at all. That definition was adopted for the sake of making the idea more simple; but, as I have, on several occasions, noticed that professors of electrical engineering have published articles in the technical journals in which, the magnetic lines being represented by vortex rings, they have stated that these rings rotated around the axis of the wire as well as around the axis of the vortex, it may not be so clear as it was originally thought to be."*

S.—"And still I am at fault. Surely this unit magnetic pole—"

E. U. M.—"There *is* no unit pole. True simplicity is obtained by defining things in terms of other things which cannot exist, calling them by names which are as misleading as it is possible for them to be, multiplying them by all sorts of constants, and stirring the whole thing up with a stick. By giving eight or ten names to the same quantity and using the same term with different significations in different connections† still further advantages are obtained. By a judicious extension of these principles and the adoption of still other practical units it is hoped in time to have a system which *no* one can understand."

I jest with tears in my eyes because I have to teach the relations between these units to students. I could get through the work in about one-third of the time if it were not for the inconveniences of the practical units and the names.

How much better it would be to call a certain quantity the voltage, the integral of it the voltance, the intensity of it the voltivity, and the absolute unit itself the volt. By following this system, 110 volts would then be 11 bega-

* For a recent instance, since the above was written, see *Weidemann's Annalen*, No. 12, 1899.

† As, magnetic moment of a magnet, and of a magnetic shell, the moment of a magnetic shell having to be multiplied by its area to get its moment considered as a magnet.

volts, and there would be no practical units, and all units would be connected by equations without constants. Similarly Gilbertage, Gilbertance, Gilbertivity and Gilbert. As regards symbols, E would stand for voltance, F for voltivity and $\dot{E}$ for time rate of change of voltage.

Is there no hope for a return in 1900 to a rational system of absolute units, names and symbols? This would also give us a chance to get rid of the 4π factor, as suggested by Heavyside.

EQUATIONS OF ENERGY.

The equations expressing electric and magnetic phenomena are four in number; *i. e.*,

$$Q\,P = M\,L^2/T. \tag{1}$$

$$\varkappa\,\mu = T^2/L^2 \tag{2}$$

$$Q\,\mu = L\,T \tag{3}$$

$$P\,\varkappa = M/L \tag{4}$$

where Q = quantity of electricity
P = quantity of magnetism
$\varkappa$ = specific inductive capacity
μ = permeability
M = mass, L = length and T = time.

From these we get the following equations:

$$\frac{Q^2}{\varkappa\,L} = \frac{M\,L^2}{T^2} = \text{energy (electric)} \tag{5}$$

$$\frac{P^2}{\mu\,L} = \frac{M\,L^2}{T^2} = \text{energy (magnetic)} \tag{6}$$

$$\frac{Q\,P}{T} = \frac{M\,L^2}{T^2} = \text{energy (electro-magnetic)}. \tag{7}$$

To go more into details, we may separate the L *s* into L_x L_y and L_z axes, where L_x represents the axis in which the electric force acts, L_y that in which the magnetic force acts, and L_z the axis at right angles to both. We then have:

$$\frac{Q^2}{\varkappa} = \frac{M\,L_x\,L_y\,L_z}{T^2} \tag{8}$$

$$\frac{P^2}{\mu} = \frac{M L_x L_y L_z}{T^2} \quad (9)$$

$$\frac{Q P}{\kappa^{\frac{1}{2}} \mu^{\frac{1}{2}}} = \frac{M L_x L_y L_z}{T^2} \quad (10)$$

$$Q = \frac{M}{T} \quad (11)$$

$$P = L_x L_y \quad (12)$$

$$\kappa = \frac{M}{L_x L_y L_z} \quad (13)$$

$$\mu = \frac{L_x L_y T^2}{M L_z} \quad (14)$$

$$E = L_x^2 / T \quad (15)$$

$$F = L_x / T \quad (16)$$

$$G = M L_x / L_z T^2 \quad (17)$$

$$H = M / L_x T^2 \quad (18)$$

We can now find out how the energy is stored up and the direction of the faces.

Take equation (8).

If we have a condenser with an electric charge on it, we get

$$\frac{Q^2}{2} \div \left(\frac{\kappa \times \text{area}}{\text{dist. between plates}}\right) = \frac{M^2}{T^2} \times \frac{L_x L_y L_z}{M} \times \frac{L_x}{L_y L_z} = \frac{M L^2_x}{T_2}$$

Or, if we have a condenser of charge Q and a certain capacity, the energy stored up in the condenser will be equal to half the square of the charge, divided by the capacity, and will be given out by motion along the x axis, *i. e.*, the force is along that axis.*

It will be noted that the capacity of a sphere in vacuo is generally given as its radius, or L_x. It is, however, the area of the sphere divided by 4π times the radius, or $L_y L_z \div 4\pi L_x$.

* The factor ½ comes in by reason of the fact that there is no voltage to commence with, and it is $\frac{Q}{\kappa}$ when the charging is finished, hence the average value is $Q/2\kappa$.

When the bodies are very far apart the capacity depends very little on the distance, but is proportional to the radius of the bodies. Here there is no force resisting a change of the distance between the bodies, but the force now comes in if we try to change the radius, and hence a soap bubble, as is well known, will tend to expand when charged.

Since electric energy is given by

$$\frac{Q}{2}\frac{L_x}{\varkappa}\frac{L_x}{L_y L_z} = \frac{M L_x^3}{T^2}$$

the energy per cubic centimeter is given by

$$\frac{M L_x^2}{T^2} \div L_x L_y L_z = \frac{M^2}{T^2 L_y^2 L_z^2} \times \frac{L_x L_y L_z}{M} = \left(\frac{Q}{\text{area}}\right)^2 \times \frac{1}{\varkappa}$$

or inserting the proper numerical coëfficient, which, if we use the C. G. S. electrostatic system, is

$$\frac{1}{8\pi}$$

* Since unit quantity $= 4\pi$ lines and the average value of $\frac{D}{\varkappa}$ is $\frac{1}{2}$ the final value.

we get

$$\frac{D^2}{8\pi\varkappa} \tag{19}$$

equals the energy in ergs per cubic centimeter stored up in electrostatic field. Since, if we allow the cube to shorten up along the x axis, the energy will vary as the length along that axis, this same expression gives the force per square centimeter of surface perpendicular to the x axis, or the stress per unit area.

The magnetic formulæ are similar. From equation (9) we get

$$\frac{P^2}{L} \div \left(\frac{\mu \times \text{area}}{\text{dist. between plates}}\right) \frac{L_x^2 L_y^2}{1} \times \frac{M L_z}{L_x L_y T^2} \times \frac{L_y}{L_x L_z} = \frac{M L_y^2}{T^2}$$

Energy per cubic centimeter and stress per square centimeter equals

$$\frac{B^2}{8\pi\mu}$$

We may make various permutations and combinations of these symbols by substituting values taken from equations previously given. Thus,

$$\frac{D^2}{8\pi\varkappa} = \frac{DV}{8\pi} = \frac{V^2\varkappa}{8\pi}$$

$$\frac{B^2}{8\pi\mu} = \frac{BH}{8\pi} = \frac{H^2\mu}{8\pi}$$

If we have a piece of glass in an electrostatic field the energy per cubic centimeter is, in the space where the glass is, $D^2/8\pi\varkappa$. If the glass be moved 2 centimeters away, the energy in the space formerly occupied by the glass is now $D_1^2/8\pi\varkappa_1$. In the place where the glass now is the energy was formerly $D_2^2/8\pi\varkappa_2$, and is now $D_3^2/8\pi\varkappa$. The total loss of energy in the space where the glass was at first is therefore

$$D^2/8\pi\varkappa - D_1^2/8\pi\varkappa_1$$

and the gain at the second place is

$$D_3^2/8\pi\varkappa - D_2^2/8\pi\varkappa_2$$

The total change of energy in the field at these points is therefore the difference between the loss and gain, and as this was caused through a motion over a space of 2 centimeters, the average force (equals energy ÷ distance moved) is

$$2\left[(D_3^2/8\pi\varkappa_1 - D_1^2/8\pi\varkappa) - (D_3^2/8\pi\varkappa - D_1^2/8\pi\varkappa_1)\right]$$

Suppose we have two plates, each 10 square centimeters in area and 1 centimeter apart, each plate charged with a quantity of electricity Q, the sign of the one quantity being + and that of the other —. Then D equals $4\pi Q/10$, and the energy (supposing the lines not to spread but to move straight from one plate to the other) per cubic centimeter of the space between the plates (which are supposed parallel to one another) is $D^2/8\pi\varkappa$. If now one of the plates be moved back a distance dl, there will now be an additional volume of space between the plates of $10 \times dl$ square centimeters. If the charge remains ~~the~~ same, the same number of lines pass across each square centimeter of

the intervening space as before, and the energy per cubic centimeter is the same as before. But there is now a volume of $1 + d\,l$ cubic centimeters between each corresponding square centimeter of area of the plates, and the energy has therefore increased by $D^2\,d\,l / 8\,\pi\,\varkappa$ for each square centimeter of surface. And this increase is due to a motion $d\,l$, so the force is $D^2\,d\,l / 8\,\pi\,\varkappa \div d\,l$, or $D^2 / 8\,\pi\,\varkappa$, per square centimeter of the plates. The total force acting to pull the plates together is therefore $10\,D^2 / 8\,\pi\,\varkappa$.

Suppose next that the two charged plates are fixed and a sheet of glass 1 centimeter thick and 10 square centimeters in area is slid in between them, the charge remaining constant. The energy in the space between the plates was originally, if they were separated by air, $10\,D^2 / 8\,\pi\,\varkappa_1$. It is now $10\,D^2 / 8\,\pi\,\varkappa$. Since $\varkappa$ for glass is greater than $\varkappa_1$ for air (the latter being 1), the energy of the whole system, when the glass is between the conducting plates, is less than it was previously. Consequently the glass plate will tend to slide in of its own accord. If it has to move through a space of 5 centimeters to do this, the average force tending to move it will be

$$10\,(D^2 / 8\,\pi\,\varkappa_1 - D^2 / 8\,\pi\,\varkappa) \div 5 \text{ equals } 2\,(D^2 - D^2 / \varkappa) / 8\,\pi.$$

This amount of energy is withdrawn from the dielectric and changed into mechanical energy through the motion of the glass plate. If we fasten a string to the glass plate it may pull up a weight and so store the energy in the form of gravitational energy. If we simply allow the glass plate to swing, it takes on a velocity and the energy becomes energy of inertia, which gradually fritters itself away, if there be friction, into heat.

As another case, suppose the voltage to be kept constant. The original energy per cubic centimeter was $D^2 / 8\,\pi$, equals $F\,D / 8\,\pi$. The energy after the movement of the plate is $D_1^2 / 8\,\pi\,\varkappa = F\,D_1 / 8\,\pi$, for since the voltage has been kept constant and $\varkappa$ has increased and $D = \varkappa F$, D must have increased to some other value, D_1. The difference of energy per cubic centimeter is therefore

$$F\,(D_1 - D) / 8\,\pi.$$

But work has now been done in two ways, first by bringing fresh electricity on to the plates of the condenser, and secondly in the movement of the plate of glass. The former amount is equal to $F(D_1 - D)/4\pi$, for quantity of electricity × voltage equals energy, and in this case the quantity is brought up to a constant potential and not, as when the condenser was first charged, to a potential gradually rising from zero to F, and whose average value was therefore 1/2 F.

But $F(D_1 - D)/4\pi$ is greater than $F(D_1 - D)\,8\pi$, and the difference, $F(D_1 - D)/8\pi$, must have been spent on the motion of the glass plate. Since there are 10 cubic centimeters, the total so spent will be $10\,F(D_1 - D)/8\pi$, and if the amount of motion is as before 5 centimeters, the average force will be $2\,F(D_1 - D)/8\pi$.

Since $D = \varkappa F$, and $\varkappa =$ unity in the case of air, this formula reduces to $2(D_1^2 - D^2/\varkappa) \div 8\pi$, as before.

We thus see that the force acting to suck in the glass plate is the same whether the charge or the voltage is kept constant, but that in the former case the energy of the whole system is lowered by an amount $10(D_1^2 - D^2/k)\,8\pi$, whilst in the latter case it is increased by the same amount. It is for this reason that twice that amount had to be spent in bringing the additional charge up to the given potential.

[*To be continued.*]

BOOK NOTICES.

The Rise and Development of the Liquefaction of Gases. By Willett L. Hardin, Ph.D., Harrison Senior Fellow in Chemistry in the University of Pennsylvania. New York: The Macmillan Company. 1899. John Wanamaker, Philadelphia. (Price, $1.50.)

The author has given us in convenient form the important data bearing on the history of the subject of the liquefaction of gases, which are scattered through the periodical literature of the past thirty years. The scientific investigator of the subject and the inventor who is chiefly interested in the practical applications of liquefied gases will find Dr. Hardin's work equally serviceable. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, May 16, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 16, 1900.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 375 members and visitors.

Additions to membership since last report, 18.

Dr. A. E. Kennelly, Messrs. Carl Hering, Louis E Levy and W. C. L. Eglin were named as delegates to represent the Institute at the various scientific and technical congresses to be held in connection with the Paris Exposition.

Prof. Arthur J. Rowland gave a historical sketch of the various methods of incandescent lighting. Mr. George S. Barrows supplemented the remarks by Professor Rowland with an account of the latest improvements in the art, used by the Welsbach Company, and illustrated the subject by exhibiting several improved forms of the Welsbach mantle and burners, and with a series of lantern slides, showing the various steps in the manufacture of the Welsbach mantles.

Mr. Moriz Burger, of New York, gave a description of the Burger and Ostergren coil machine for liquefying air, and gave an account of the recent researches of Prof. Raoul Pictet in the separation of air into its constituent parts, and of the industrial uses of oxygen, nitrogen and carbon dioxide. This communication was illustrated by numerous experiments.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, May 2, 1900.*]

MR. HENRY R. HEVL in the chair.

The following reports were adopted:

National Export Exposition.—Exhibit of the U. S. Geological Survey. [Referred by the Bureau of Awards.]

Report.—For the reasons set forth in the following report, the sub-committee charged with this investigation recommends the grant of the Elliott Cresson Medal to the U. S. Geological Survey, viz.:

ABSTRACT.—"The large space occupied by the U. S. Geological Survey is richly and instructively filled with the products of the industry of this useful branch of the Government.

"The exhibits of the Survey comprise maps, photographs, publications and a typical series of rocks.

"I. The maps are (*a*) geographical; (*b*) topographical, in contour curves or in relief, and (*c*) geological and statistical, *i. e.*, colored to represent the geological structure and the distribution of deposits of economical value. Besides the above are vertical sections where these seem of advantage to the comprehension of the subject.

"In all these maps the best methods and workmanship of modern cartography have been employed. For the topography, the system of contour curves, displayed in the large atlas maps of the Hayden survey, retains in the later maps an equal excellence of finish, but represents a greater accuracy of field work.

"There are five specimens of relief maps reproducing (1) the United States on a scale of 1 inch to 12 miles horizontally, and to 1·2 miles vertically, the vertical scale being exaggerated to ten times the horizontal for the purpose of better marking the relief; (2) the Atlanta-Chattanooga district; (3) Nebraska; (4) Tennessee; (5) Connecticut. These models show the perfection to which Prof. J. P. Lesley brought this kind of work in the late Second Geological Survey of Pennsylvania.

"A photograph of one of these models, appropriately illuminated, illustrates the device of Professor Lesley for distributing the comprehensive knowledge imparted by these instructive plans as widely as the printed pages of the reports.

"In all these maps the accuracy of registration of the several parts upon each other, as well as the constancy of the coloring of the different sections, are worthy of special attention, because they indicate the successful solution of two of the most difficult problems in section map-making.

"A large lithographic press in another part of the building is in active operation, under the direction of the U. S. Geological Survey.

"II. The photographs of the U. S. Geological Survey have long been famous. In no other national geological survey have photographic illustration been so lavishly and judiciously employed to illustrate the text of the technical studies. But beside this purpose, the splendid colored transparencies of Mr. J. K. Hiller, presenting in brilliant natural colors the Grand Cañon of the Yellowstone Park, and another typical Western view, are in the front rank of their branch of the photographic art.

"III. The publications of the Bulletins and Annual Reports of the Geological Survey, among which are included the statistical record of the mineral industry down to the end of the year 1898, exhibit the information given to the people since 1880. The only criticism to be made is the arbitrary adoption of this last date, as if it were the commencement of national geological work here, though, of course, this choice could be justified by the present title of the service. In point of fact, however, the publications which first called the attention of the world to the admirable work this country was doing in the systematic study of her resources, and which made possible the organization of the present, were issued for ten years anterior to 1880.

"IV. Following the example first set in Germany, the Survey has prepared a series of 150 specimens of typical rocks, whose names recur frequently in the reports. The value of such collections cannot be overestimated. They make clear the descriptions of complicated geological conditions, and put an effective check upon that natural enemy of geological science, the petrographic name-maker.

"In the sense and for the purpose of a demonstration to the public of the usefulness and industry of a great public work for which the public pays, this exhibit is deserving of the highest praise, and your committee recommends the Silver Medal and a diploma, the highest award within its gift.

"It recommends in addition the reference of this exhibit to the Committee of Science and the Arts of the Franklin Institute for further investigation, with a view to special reward of merit." [*Sub-Committee*, Theo. D. Rand, Chairman; Persifor Frazer.]

National Export Exposition.—Laird, Schober & Co.'s Exhibit. Boots and Shoes. [Referred by the Bureau of Awards.]

ABSTRACT.—For quality of material, beauty of design, expert workmanship and proper proportions of the products of these manufacturers the award is made of the Edward Longstreth Medal of Merit. [*Sub-Committee*, J. Ware Jones, Chairman; Howard L. Townsend, Wm. C. Benkert.]

National Export Exposition.—Exhibit of A. J. Holman & Co. Subject, Bibles.

ABSTRACT.—The report of the Investigating Committee, after due re-examination of the exhibit of A. J. Holman & Co., of Philadelphia, is substantially as follows:

"One of these productions, however, merits the special consideration of your body, namely, the edition known as the 'Linear Parallel Bible.' This work presents the varying passages of the King James and the Revised Version of the Scriptures in a manner at once original and effective. The versions are placed in juxtaposition, in close parallel lines, the older rendering in the upper and the revised version in the lower line, both printed in a plain and clear type combination, which affords the reader at a glance a direct comparison of the two renderings, including all the variæ, from changes of the text to the minutest detail of the changes in punctuation, many of the latter being as important as those of the text.

"For students especially this innovation is of marked value, as the ordinary method of presenting variations of this character by parallel columns or marginal notations is extremely taxing both to the eye and to the mind of the investigator.

"The mechanical execution of this edition is such as to make it an example of the most advanced art in book-making, 1,000 pages being comprised in a thickness of only ⅝ of an inch, while with this extreme thinness the paper combines the requisite qualities of strength and opacity of texture.

"In recognition of the originality of design in this work, and of its technical excellence, your sub-committee recommends that the Franklin Institute award to Messrs. A. J. Holman & Co. the Edward Longstreth Medal of Merit." [*Sub-Committee*, Louis E. Levy, Chairman; John R. McFetridge, Stephen Greene, J. L. Shoemaker, F. Oldach.]

National Export Exposition.—Exhibit of the Pencoyd Iron Works, Pencoyd, Pa. [Referred by the Bureau of Awards.]

This report is reserved for publication in full.

The award of the Elliott Cresson Medal is recommended to the exhibitors for remarkable progress exhibited in bridge and other structural engineering. [*Sub-Committee*, Thos. P. Conard, Chairman; H. F. J. Porter, Joseph Hartshorne, Harrison Souder, Jacob Y. McConnell.]

National Export Exposition.—Improvements in Filing Cabinets. Wm. H. Tucker, Newark, N. J. Report:

ABSTRACT.—This application has reference to certain improvements in Filing Cabinets invented by Wm. H. Tucker, of Newark, N. J., including a

support for bill file holder, patented December 18, 1883 (No. 290,497); a file box, patented on same date (No. 290,498); a system of indexes, for use in connection with appliances for filing documents, patented July 14, 1891 (No. 455,807), and also to certain improvements in bill files and card indexes, invented by Emil J. Bein, of Newark, N. J., patented July 4, 1899 (No. 627,967), and August 14, 1899 (No. 631,772).

These improvements are embodied in the Letter and Document Files and Card Index Cabinets manufactured by the Tucker File Company, of Newark, N. J., and formed the subject-matter of an investigation and report by the undersigned, acting as a Jury of Awards at the National Export Exposition of 1899 (see Appendix).

To that report, which is hereby specifically confirmed, your sub committee takes this occasion to add a consideration of the Index System invented by Wm. H. Tucker, which, while quite adapted for use in connection with any document file whatever, is given a marked degree of efficiency by the several carefully designed devices applied to the Tucker Cabinets, as noted in the former report already referred to. These Letter and Document Files, as thus completed with a comprehensive index, together with the ingeniously-contrived card-index cabinets, afford a means and a system of filing documents for ready reference and easy access which appears to leave nothing to be desired.

In recognition of the improvements effected in the design and construction of Files for Documents, and in the system of indexing the latter, your sub-committee recommends the award to William H. Tucker of the Edward Longstreth Medal of Merit; and in recognition of improvements in Letter File Clamps and Index-card Holders, your sub-committee recommends the award to Emil J. Bein of a Certificate of Merit. [*Sub-Committee*, Louis E. Levy, Chairman; F. Oldach, J. L. Shoemaker.]

As the action of the Bureau of Awards is referred to specifically by the sub-committee for information respecting the reasons for its award, the report in question is herewith reproduced:

APPENDIX.

COPY OF REPORT OF THE JURY OF AWARDS, N. E. E., 1899.

The exhibit of File Cabinets made by the Tucker File Company, of Newark, N. J., presents a series of novel and highly convenient appliances. Notable among these is a clamping device by which the papers filed in the receptacles are compressed so as to utilize space to the utmost and to maintain the papers in their original compactness, while at the same time the device is so arranged as to permit the contents of the file to be completely freed for easy access at any point. The automatic suspension device by which the file is held in place for convenient examination is thoroughly efficient. The arrangement of a supporting slide for the card index files, and the devices for holding and conveniently freeing the index cards, are worthy of special commendation.

The thoroughness with which the details of these File Cabinets have been wrought out is fully equalled by the mechanical excellence of their construction, and, in view of these aspects of the exhibit, the Committee of Judges recommend the award of the Exhibition Silver Medal and Diploma of the

Franklin Institute to the exhibitors, and also the reference of these constructions to the Institute's Committee on Science and the Arts for due consideration of that body.

(Signed) LOUIS E. LEVY, *Chairman.*
JOHN R. MCFETRIDGE,
STEPHEN GREENE,
FREDERICK OLDACH,
J. L. SHOEMAKER.

Basin System.—C. L. Riker, Newburgh, N. Y.

ABSTRACT.—This invention consists of a complete washstand with fittings, containing many desirable features, being a self-contained fixture with a novel application of the siphon single-pipe waste. The report finds that the system in respect of design of details, mechanical construction and workmanship is worthy of commendation, and awards the Edward Longstreth Medal of Merit to the inventor. [*Sub-Committee*, Frank P. Brown, Chairman; John E. Evanson, Wm. Copeland Furber, John Joyce.]

Variable-Speed Countershaft.—Milton O. Reeves, Columbus, Ind.

(Referred back to sub-committee for amendment.)

Passed first reading:

Machine for Tangible Writing for Touch Reading.—Wm. B. Wait, New York City.

National Export Exposition.—The Welsbach System of Lighting. Welsbach Commercial Company, Philadelphia.

National Export Exposition.—International Incandescent Light Company's Lamp. International Incandescent Lamp Company, Philadelphia.

National Export Exposition.—Improvements in Carriages and Wagons. Chas. S. Caffrey Company, Philadelphia.

Lever and Ratch Attachment.—Waterbury Tool Company, Waterbury, Conn.

(These were held over for one month.)

Method of Obtaining Energy for Automobiles.—John Stolze, Reading, Pa.

W.

SECTIONS.

ELECTRICAL SECTION.—*Stated Meeting*, held Tuesday, April 24th. Prof. W. S. Franklin in the chair.

The paper of the evening was read by Mr. J. Franklin Stevens, of Philadelphia. Subject, "Electrical Instruments."

The paper sketched briefly the development of the art embodied in the manufacture of commercial indicating instruments, stating the most desirable qualities of modern types. The systems most commonly employed were each briefly discussed, principle of operation explained and their limitations described. Stress was laid on the fact that there is no type of instrument which is absolutely universal, and the general rules for selecting the most desirable type for any particular class of measurement were set forth. A number of details connected with the manufacture of various types of instruments were given and some special types of instruments described in detail. The deriva-

tion of fundamental electrical units was dwelt upon and the relations between primary and secondary standards described.

RICHARD L. BINDER,
Secretary.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, May 3d. Dr. Henry Leffmann in the chair.

Mr. Lyman F. Kebler gave the Section an account of a series of examinations he had made of commercial samples of gold chloride in which he had discovered a considerable difference in the quality of the various brands on the market. He said that, taking an estimated quantity of 100 ounces, the difference in actual value between the best and the worst would amount to over $150, and that between these two there were all grades of value.

Dr. Henry Leffmann quoted portions of a paper by William James Russell, recently presented to the Royal Institution of Great Britain, relating to pictures produced in the dark, in which the theory is advanced that the action is due to the formation of hydrogen dioxide.

The meeting was closed by an exhibition of lantern slides of the path of the coming eclipse of the sun, and of views of the dam on the Colorado River at Austin, Tex.

F. W. SAWYER,
Secretary.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, held Friday, May 4th. Dr. A. S. Kennelly in the chair.

The paper of Mr. H. M. Watts, read at the April meeting, on "The Proper Organization of the Modern State Weather Service," was the special subject of the evening.

Mr. Watts' remarks were informal. He exhibited two reports, one, that of the Maryland State Weather Bureau, and the other our own, which was an unbound pamphlet, very valuable, as far as it went, but not to be compared with that of Maryland. The Maryland service had an appropriation of $2,000 per year for its maintenance, which had been granted with the proviso that none of it should be spent for salaries. As a consequence, it had all been used upon the publication, which was composed of monographs on meteorology, physiography and kindred subjects, written by specialists, the collected observations of the United States Weather Bureau having been used as data. Mr. Watts thought that the adoption of something similar in this State would prove of great value, and suggested that the Section take steps to interest other institutions of learning throughout the State in the matter, with the view of getting an appropriation of, say $3,000, and organizing a bureau modeled so far as conditions would admit on that of Maryland. The subject was discussed by Messrs. Dey and Townsend.

On motion of Dr. Wahl, the President was authorized to appoint a committee to confer with the various technical institutions throughout the State, with a view to carrying out Mr. Watts' suggestions.

The President announced as the next subject "The Consideration of the Subject of Making Observations and Records of the Total Solar Eclipse of May 28th."

Dr. Wahl, Mr. Weinrich, Mr. Watts and others took part in the discussion which followed.

The President stated that the Section, in conjunction with the Section of Photography and Microscopy, had arranged to issue the following joint bulletin :

For the benefit of those who may not be familiar with modern methods of observing and recording solar eclipses, but who intend to observe the eclipse of May 28, 1900, the following suggestions have been prepared, with the aid of information contained in a supplement to the *American Ephemeris* (*Nautical Almanac*) for 1900, as published by the Bureau of Equipment of Washington. Additional information has also been obtained personally from Professor Doolittle, of the Flower Observatory.

Amateur observers, and those not provided with elaborate astronomical apparatus, may be able to furnish valuable data from their observations in the following four ways :

(1) Sketches of the corona with the naked eye.

(2) Observations of such moon's shadow bands as may be observed.

(3) Observations of the times of contacts.

(4) Photographs of the corona.

Useful sketches can be made with the naked eye, but they must be limited to outlines or particular features, if satisfactory records are to be obtained. Co-operation of several sketchers is advantageous. Sketchers should avoid fatiguing the eye by too frequent observations of the eclipse while partial, and should refrain from making any observation for the five minutes preceding totality.

The following directions are given for sketching : Upon a sheet of paper, say 9 x 12 inches, a black disc 1¼ inches in diameter is drawn, with a series of projecting radii at angles of 30°. The positions of various parts of the corona as seen against the sky are best indicated by reference to a vertical line obtained by mounting a plumb-line so that it is seen over the moon's center. The diagram upon which the drawing is to be made is placed on any convenient support, so that the lines marked "top" and "bottom" are in the plane of the plumb-line, the top corresponding to the top of the string. The members of the sketching corps should do some preliminary practice, each sketching a particular quadrant from a drawing of a corona placed at the angular height of the sun. The time of practice in drawing should be a little less than the actual duration of totality. White chalk on purplish-blue paper gives excellent results.

In regard to the fourth or photographic method, the results of the East Indian eclipse expedition in 1898 have shown that valuable photographs may be obtained with instruments of moderate dimensions. Among the best results on that occasion were those obtained by amateurs, one with a Dallmeyer stigmatic lens, and one with a Dallmeyer rapid rectilinear of 2·125 inches aperture, only the back lens being used, which gave an equivalent focus of 32·5 inches.

Plates of ordinary sensitiveness (which are more convenient than extraordinarily rapid ones) will require an exposure of from one to two seconds (referred to $\frac{f}{a} = 16$). The camera should be set by bringing a well-defined object, distant about half a mile, into sharp focus at the center of the plate. The actual image of the sun will be a small part of the field, for the focal

length of the lens in inches will be approximately the diameter of the sun's image in hundredths of an inch. Negatives must not be retouched or otherwise altered. Driving apparatus for the camera is not necessary, very good results having been obtained with common instruments, but, of course, photographs taken with cameras provided with a driving clock or other device for keeping the image stationary on the plate are most useful.

When $\frac{\text{Equivalent Focus}}{\text{Aperture}}$ or $\frac{f}{a}$ is not greater than 15, and the focal length is not greater than 5 feet, the blurring of the image in a stationary camera during an exposure of $\frac{1}{4}$ second is only $\frac{1}{200}$ of an inch; practically imperceptible.

It is of the highest importance that the camera be rigidly mounted. Plates should be so marked as to enable the operator to determine after development which was the top of plate as exposed.

The total eclipse of the 28th of May commences on the earth at approximately 15 minutes past 6 A.M., Eastern time of the seventy-fifth meridian, and ends at about 33 minutes past 10 o'clock A.M. of the same Eastern time. During this time the moon's shadow will have passed nearly half way round the northern hemisphere, and the period of totality at any one point in the United States is but little over one minute, being about 72 seconds in New Orleans and about 90 seconds near Norfolk, Va. The eclipse which is visible in the early morning in the United States is visible in Europe and in Northern Africa some two hours later in actual time, and consequently photographs of the corona obtained in the United States will be comparable with those obtained on the other side of the Atlantic two hours later, which may possibly lead to valuable results. The path of totality is central over New Orleans about 8 A.M., local time, and passes northeasterly across the United States, passing near to Greenville, Ala.; Union Springs, Ala.; Talbot, Ga.; Newberry, S. C.; Lancaster, S. C.; Rockingham, Edgecombe, Gatesville, N. C., and passes into the Atlantic about seventeen miles south of Norfolk, Va. Although this is the central line, totality for a diminished period will be visible at any point within about twenty-five miles on either side of this line. Near Norfolk the totality will take place about 9 A.M. Eastern time (8.52 A.M.).

W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, May 9th. Mr. Joseph Richards in the chair.

The meeting was devoted to a continuation of the discussion of the paper of Mr. Kreuzpointner, which was left unfinished at the previous meeting.

The principal speaker was Mr. A. E. Outerbridge, Jr., who proceeded with the consideration of the subject in so far as it related to cast iron.

Mr. Wm. R. Webster and Prof. Henry M. Howe, of Columbia University, New York, contributed to the discussion of Mr. Outerbridge's remarks, and the further consideration of the subject was postponed.

Owing to the lateness of the hour, the paper presented by Mr. B. S. Lyman, on "Underground Water," was read by title, and referred to the Committee on Publication.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, May 10th. Prof. John F. Rowland, Jr., President, in the chair.

The paper of the evening was read by Mr James S. Merritt, on "Expanded Metal, with Incidental Reference to its Application in Concrete Construction."

The speaker said in substance:

"Expanded metal has become much more widely used than was originally anticipated by the inventor, J. F. Golding, of Chicago. He intended to make window screens, trellis work, etc., and called the material 'slashed metallic screening,' afterward 'expanded metal' (French, 'metal deployé,' German, 'streckmetal')."

The speaker gave a description of the original method of cutting expanded metal and of the improvement introduced by Mr. Golding, in 1894, which permits the use of much heavier steel than formerly. The cutting and the opening out of expanded metal are done simultaneously. No steel is wasted, as there are no pieces punched out. The finished sheets are from three to eight times as large as the original sheets of steel. The process requires good stock and careful adjustment of the shear blades, which must be kept sharp. Numerous other operations, such as annealing, pickling, etc., are necessary for a perfect product.

The principal use of expanded metal at the present day is in fireproof construction of buildings and as a "binder" in concrete structures of all kinds. The extent of its use is shown by the fact that over 9,000,000 square feet, or 200 acres of various grades of expanded metal were used in the buildings of the Paris Exposition for floors, exterior walls, etc. This is a little greater than the area bounded by the Delaware and Schuylkill Rivers, Market and Sansom Streets. There is scarcely a prominent building in the United States which has been completed during the last ten years that does not contain a considerable quantity of expanded metal. Examples: Library of Congress, Washington; Carnegie Library, Pittsburgh; Free Library, Boston; City Hall, Philadelphia; Masonic Temple, Boston. Many illustrations were shown of the details of such work. Expanded metal is used by the Bell Telephone Company, of Philadelphia, in a sewer passing through their large manhole at Seventeenth and Filbert Streets. By the combination of expanded metal with concrete in such a way that the steel resists the tensile stresses, concrete can be used in many fields from which it has hitherto been debarred on account of its low tensile strength. Engineers are using it all over the world to reinforce concrete in the construction of bridges, piers, sea walls, docks, etc. Expanded metal is also used for many curious purposes, such as riffles in placer gold mining, brake shoes, bird-cages, door-mats, etc.

DANIEL EPPELSHEIMER, JR.,
Secretary.

CHEMICAL SECTION.—*Stated Meeting*, held Tuesday, May 15, 1900. Dr. W. J. Williams, President, in the chair.

The paper of the evening was read by Dr. S. P. Sadtler. Subject, "A Historical Review of the Subject of Mineral Tanning."

The speaker gave an interesting address covering the application of alum, iron and chrome salts and formaldehyde for tanning skins, and illustrated

the subject by the exhibition of a number of specimens of each species of tanning.

(Referred for publication.)

WM. E. RIDENOUR,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Tuesday, May 22d. Mr. Joseph Richards in the chair. Twenty members present.

The Section voted to change the evening of the stated meeting from the fourth Tuesday to the third Thursday of each month, except in July and August.

Mr. C. H. Bedell, of Philadelphia, presented a communication on "An Electrical Revolution Indicator, and the Pfatischer Electrical Steering Gear," which was discussed by Professors Hoadley and Stine, and referred for publication. W.

CLOSING EXERCISES OF THE SCHOOL OF NAVAL ARCHITECTURE.

The closing exercises of the School of Naval Architecture were held in the lecture room of the Institute on Friday evening, May 18th, at 8 o'clock.

Mr. James Christie presided.

Brief addresses appropriate to the occasion were made by the chairman; Dr. Wahl, Chairman of the Committee on Instruction, and Mr. Alex. J. Maclean, Director of the School.

The Director stated that thirty-eight pupils had been enrolled in the first session of the school, and gave an encouraging account of the work of the students and of the future prospects of the school.

The Director of the school made the following report:

"The Franklin Institute School of Naval Architecture commenced on Friday evening, October 20, 1899, with twelve students, and at each successive Friday evening received increments to registration until the maximum thirty-eight was reached early in January, 1900. During this term of twenty-seven weeks the average attendance has been sixteen.

"The course of instruction in the several branches of naval architecture was followed on parallel lines, embracing more than one-half of the synopsis issued at commencement. Blue-prints of details of construction of the different classes of vessels, both for the naval and mercantile marine, were lent to the students, from which they were able to make sketches applicable to lectures given. Homework, in the form of calculations similar to those described and worked in classroom, was performed by the students, the majority of the students showing marked ability."

Prizes, consisting of cases of draughting instruments and technical books, were distributed on behalf of the donors, Messrs. Chas. H. Cramp, Clement A. Griscom, Lewis Nixon and the Director of the School.

The recipients of the prizes were: Fred. A. Coolidge, Wilmington, Del.; Henry T. Darlington, West Chester, Pa.; James A. Kelly, Chester, Pa., and Wm. H. Balls, Philadelphia. W.